THE OHIO JOURNAL OF SCIENCE

VOL. XXXIX MARCH, 1939 No. 2

EXTRAORDINARY DEVELOPMENTS AT OR NEAR THE ENDS OF EVOLUTIONARY SERIES.

STUDIES IN DETERMINATE EVOLUTION, XI*

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When the taxonomic groups of plants are arranged in proper phylogenetic series in agreement with their advancement in complexity of reaction systems, a remarkable situation becomes evident that could not be recognized so long as taxonomy was developed along the lines of the old, haphazard teleological hypothesis of origins. It is found that at or near the ends of many orthogenetic series, especially the higher ones, one frequently meets with very unusual, peculiar, or extraordinary characters and complexities which are not in evidence or only very rarely so in the lower levels of the series. Not only are these extreme developments unusual and particular but they are frequently bizarre and grotesque, each series usually having some characteristic structures or reactions not evolved in other series, even though the general evolutionary developments have been essentially similar. Curiously enough these extraordinary characters were formerly often taken to indicate primitiveness; as for example, *Zea mays* L. was put at the bottom of the grass series although it has a most remarkable array of unique and highly evolved characters.

When one studies a group of organisms from the phylogenetic point of view, it is always advisable to look for these unusual characters near the supposed limits of the main lines and near the ends of the various subordinate series. It is impossible at the present time to form an adequate conception of the cause or causes of this remarkable biological phenomenon, but it appears to be associated with highly specialized and com-

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plex aggregations of hereditary potentialities in the evolved protoplast. When the protoplast becomes filled, so to speak, with a great aggregation of hereditary potentialities these extraordinary mutations seem to occur very frequently when compared with the more uniform accumulation of characters appearing at the lower levels of the phyletic series.

In the present study a general view of some of these extraordinary forms is given, the examples being taken mostly from the higher, vascular plants. A few, however, are from the lower plant series in which remarkable structures are by no means absent.

Among the most bizarre forms are a number of advanced gastromycetous fungi; like *Dictyophora phalloides* Desv. This is a mushroom with a very fancy lace-like "petticoat." The lower true fungi are mostly composed of a loose, branching mycelium, which, although it may react to various stimuli as light, substratum, etc., seems to have only a very slight correlative interaction between the different mycelial branches. In the highest fungi, this property of unitary correlation between the hyphae becomes truly marvelous in the development of the fruiting body. The mycelial threads in their growth and branching weave patterns as astonishing in their complexity as a complicated tapestry. *Dictyophora phalloides* represents an extreme example of such reaction. It is difficult to believe that such a plant exists if one has never seen it. It has a pure white stipe, a cap of greenish color, and, as stated above, a white-lace-like petticoat, with polygonal and hexagonal meshes, suspended around the stipe below the spore-bearing body. It has, moreover, a most vile odor combined with its wonderful beauty of form and color.

There are various extreme culminations among the higher algal series. In the Characeae, or stoneworts, the species of *Chara* have very peculiar and complicated sex organs, especially the antheridium. The antheridium is spherical in shape and looks externally as if composed of solid tissue, but it is really a highly organized system of filaments with long branches coiled up in the inside, the individual cells of these filaments developing the spermatozoids. The antheridia are bright red in color in decided contrast to the nearby oogonia which are green, flask-shaped bodies covered with five spiral filaments. The sexual dimorphism of these gametangia in form, structure, and color is just as extreme, even though they develop side by side on the

same branch, as the sex difference in various birds and other higher animals, which has been ascribed by the teleological selectionists to the causative operation of "sexual selection," one or the other mate being supposed to have a preference for fancy colors and unique forms. As stated, in *Chara* the red antheridia and green oogonia are situated on the same individual, but similar differences in color and form of parts surrounding the sex organs are also found in species of Polytrichum, which are among the most highly evolved unisexual mosses. The relative dimorphism is just as great as between a hen and a rooster. The absurdity of the sexual selection hypothesis becomes evident when applied to these mosses which have neither eyes nor brains with which to make a choice of mates; but in spite of great numbers of such contradictory cases, the "sexual selection" delusion has not yet entirely disappeared from a certain type of biological mind.

Our living species of *Equisetum* represent the surviving culmination type of a great group of plants that appeared far down in the geological scale. All the living species of Equisetum show an unusual development in the peltate sporophylls and in having highly hygroscopic, coiling elaters attached at one side of the spores, produced by the spiral splitting of the outer wall of the tetraspores. Another extreme condition in most of the species is the extraordinary development of silex in the cell walls, especially in the epidermis. The highest species, *Equisetum arvense* L., is an extraordinary plant because it, with its near relatives, shows an extreme dimorphism of its vegetative and reproductive, aerial shoots. The vegetative shoot is green and much-branched and survives until late autumn while the reproductive shoot is without green color, is unbranched, and dies in a few days after coming out of the ground. Such extreme dimorphism of the entire shoots is exceedingly rare in the plant kingdom.

In the Polypodiaceae, which represent the highest, homosporous, leptosporangiate ferns, an extremely unique and perfected type of sporangium, capable of throwing the spores a short distance, has developed. The heterosporous water ferns are the most advanced types in the fern phylum and also exhibit a number of unusual developments. *Azolla caroliniana* Willd. is a tiny, free-floating plant which has attained the extreme limit of leaf arrangement, the alternate, two-ranked system. In its microsporangia it develops peciular massulae,

each containing several microspores. On the surface of these massulae anchor-like processes or glochidia with septate stalks are borne. Comparable masses of microspores or pollen, but of a different structure, are found in some orchids and in milkweeds, both of which groups represent extreme developments in their phyletic lines. *Salvinia natans* (L.) Hoffm. has remarkably developed floating leaves which tend to keep the plant right side up and in addition finely dissected leaves having the appearance of roots dangling into the water. In the genera *Marsilea* and *Pilularia* highly specialized sporocarps are developed which discharge their sporangia and spores by emitting a gelatinous, elastic band or cord to which the sporangia are attached. All these characteristics are unique in the plant kingdom.

A very bizarre condition is present in the higher species of *Selaginella* which represent the most advanced stage in the living Lepidophyta. In these species, the closed vascular bundles, whose chief function is the transfer of water through the plant body, are situated in tubular cavities filled with air in the ground tissue of the stem. The bundles are suspended in the middle of the tubes by means of filaments of cells passing from the walls of the tubes to the surface of the bundles. Compared with the usual stem structure, this arrangement of the tissues certainly represents an extraordinary mechanism.

In passing from the Pteridophyta to the Gymnospermae, one discovers a pronounced advance in the complexity of the general reaction system of the cell. One is prepared to meet with odd developments as soon as one encounters the more highly evolved genera. Among the highest of the Taxodiaceae is *Taxodium distichum* (L.) Rich. which has among other remarkable features the development of large woody outgrowths or "cypress knees" from the roots and highly specialized, herbaceous, annually deciduous, feather-like dwarf branches. It also has decidedly ornamental markings on the outer surface of the carpels of the globular cone. *Sciadopitys verticillata* (Thumb.) S. & Z., another advanced type of the Taxodiaceae, is remarkable for its dwarf branches with long double needle leaves.

Among the Pinaceae, the genus *Pinus* contains the species with the most complicated reaction systems and with some very unusual structures. The peculiar combination of needle leaves (some as in *P. palustris* Mill. up to 16 or more inches long), deciduous dwarf branches, fission embryos with extraor-

dinary embryonic development, whorl of linear cotyledons, and in some species, as in *P. coulteri* D. Don. enormous, woody ovuliferous scales and zygomorphic cones, determines the pine as one of nature's most remarkable handiworks. In some species of the Juniperaceae, as in *Biota*, the oriental arborvitae, the embryogeny is even more peculiar than in the pines. The egg begins to develop about 40 embryos with long thread-like suspensors so that the whole group looks like a tiny mass of thread. A single one of these 40 fission embryos finally develops in the maturing seed. This represents about the extreme of embryo development, whether plant or animal, and appears in the highest family of the Pinales. In *Juniperus* one meets with an enormous branching abliity in some species and a minute, colored, berry-like cone with carpels permanently fused at maturity and developing a single seed in the highest species. In *Taxus canadensis* Marsh., one of the culmination types of the Taxales, the peltate stamens come to the same general form as the sporophylls of Equisetum, which an extreme Darwinist might regard as a conclusive case of mimicry. The reduction of the carpellate flower to a single ovule on a vestigial carpel lacking a blade and the development of the bright red fleshy aril around the seed are also unusual and extreme developments.

The highest class of Gymnospermae, the Gneteae, contains one of the most bizarre plants in the plant kingdom. *Welwitschia mirabilis* Hook. f. of the South-west African desert has but two great, ribbon-like, foliage leaves that grow from the base during the entire life of the individual and finally split into numerous narrow segments. The terminal bud becomes determinate when these first two foliage leaves have been produced and only reproductive buds are produced later. This species has a large number of other extraordinary characteristics which tend to make it one of the most remarkable plants in the world.

The flowering plants, or Anthophyta, are the highest and most complex of the plant phyla. They have a complement of 100 or more fundamental potentialities common to all the species of the many phyletic lines or series into which this greatest of plant groups has segregated. Thus unusually large numbers of extraordinary structures have evolved. Only a few of these can be mentioned here to illustrate the general principle. At the top of the Helobiae, the lowest subclass of monocotyls, is that extremely interesting species, *Vallisneria spiralis* L. It is an aquatic plant with long ribbon-like leaves, has the

carpellate flower on a very long spirally coiled peduncle which reaches the surface and after pollination the fruit is drawn down by this coiling peduncle and ripens under the water. The staminate inflorescence has a short peduncle with numerous minute flowers about the size of a pin head. These flowers are abscissed and float on the surface and their dehiscing stamens thus come in contact with the receptive stigmas of the carpellate flowers. It is difficult to imagine a more unique method of pollination.

The Araceae and Lemnaceae are advanced families of the Spadiciflorae which also include the palms and Pandanales. One of the extraordinary species is *Alocasia odora* (Roxb.) C. Koch, which has a powerfully odoriferous organ at the top of the spadix and a spathe that is separated in the middle by the development of a corky layer which finally causes the outer end to wither away while the lower end becomes thick and fleshy, forming a tight compartment around the zone of carpellate flowers. This bottle-like structure fills with water secreted on the inside in which the fruit develops. A number of related species have similar characteristics. Among the duckweeds (Lemnaceae) is the genus *Wolffia* which contains the smallest species of seed plants. It has a minute egg-shaped body, which floats on the surface. Its lack of roots and leaves, together with other extreme simplifications, is probably caused by a large number of acquired, inhibitory, hereditary factors. It possesses an extreme ability for vegetative multiplication, the joints separating from each other as rapidly as they are produced. This vegetative multiplication proceeds at such an enormous rate that myriads of individuals may be produced in a favorable season. Dr. L. E. Hicks found that in the drought year of 1933, a single acre in Buckeye Lake in Ohio contained a thousand times as many individual plants of *Wolffia punctata* Griseb. as there are human beings in the whole world.

The Glumiflorae are a rather highly specialized group of plants, the Cyperaceae a lower and the Gramniaceae a higher family of the group. Among the Cyperaceae an extreme development is found in *Eriophorum viridicarinatum* (Engelm.) Fern. and related species in which the ordinary perianth is replaced by a great number of elongated bristles, much like the pappus of many composites. The genus *Carex* has an odd sack-like structure around the ovulary which is not present in any of the lower sedge genera nor in any of the grasses. In such advanced species as the hop sedge (*Carex lupulina* Muhl.) the style is

elongated and bent at the lower end into a peculiar double curve. The more advanced tribes of grasses show many exceedingly interesting developments. In the Agrostideae, *Stipa pennata* L. has a fruit with a sharp point at the base and a large twisted and bent awn with a flexible, plume-like end about 12 inches long. Among the oddities in the Panicatae may be mentioned the species of *Cenchrus*, or sandburs, in which the pairs of spikelets are enclosed in a bur representing a cortical outgrowth of tissue covered with rigid, retrosely barbed prickles. In the highest tribe, the Andropogoneae, there are many remarkable plants. Teosinte (*Euchlaena mexicana* Schrad.) has husks covering the carpellate inflorescence, long hair-like styles or silks, and a most peculiar, bony and polished, box-like structure, composed of a rachis joint and an outer empty glume serving as a lid. This box contains the carpellate spikelet and mature grain. The most advanced and extraordinary grass is the Indian corn (*Zea mays* L.) with prominent prop-roots, extreme dimorphism between carpellate and staminate inflorescences, the ear and its cob enclosed in a highly evolved husk, the very long styles or silks together with very long, rapidly-growing pollen tubes, and finally with the highly developed caryopsis or grain containing in different varieties a complex assortment of endosperms of various colors—including flint, waxy, sugary, flour, starchy (dent), and pop varieties. The evolution of the grasses has culminated in a profoundly unique and useful plant.

Near the upper levels of the Liliales are the rushes and here again one finds a unique structure in some of the higher species, as in *Juncus militaris* Bigel. and *J. acuminatus* Mx., in which the leaf blades have a series of transverse diaphragms. In the Tillandsiaceae, *Dendropogon usneoides* (L.) Raf., the Spanish-moss, is an extraordinary plant in many respects. It is one of the most extreme types of epiphytic plants. The stem and very slender leaves are closely covered with translucent, silvery-scurfy, ovate-lanceolate scales, peltately attached, with an oval somewhat glandular area above the point of attachment. The stem is very slender and spirally coiled and flexuous, hanging in clustered festoons from the branches of trees. The leaves have also attained the determinate limit in arrangement, being alternate two-ranked. A very remarkable structure is shown by the very long funiculus of the seed, which splits up into a cluster of fine threads. In the Eriocaulaceae, the most extreme family of the Liliales, the flowers are minute and are collected into

disk-like heads which look much like the heads of some Composites. Some species, as *Syngonanthus anthemidiflorus* (Bong.) Ruhl., have enlarged, spreading, involucral bracts causing the inflorescence to simulate an *Anthemis* belonging to the sunflower family. The Eriocaulaceae also contain various species having their corollas transformed to a ring of hairs between the calyx and gynecium. One of the most extreme species with this peculiarity is *Lachnocaulon anceps* (Walt.) Morong.

In the Iridaceae there is a most remarkable flattening, in some species, of the leaves and aerial stem. This flattening is extreme in some species of *Sisyrinchium* and *Marica*. Species of *Iris* show extreme oddities in the petaloid stigmas and hairy crests on the sepals. Some species also have an extreme development of the solid, epigynous hypanthium, a rare structure in the flowering plants. In the two higher families Cannaceae and Marantaceae, of the Scitaminales, the flower is of the zygomorphic type but has in addition developed an inequilateral form, having thus only a half-fertile stamen, the other half being petaloid.

The Orchidaceae represent the most advanced plants among the Monocotylae with the most complicated accumulation of hereditary potentialities. In this family there are many odd and remarkable structures in the flowers, leaves and roots. An unusual development appears in some genera. The pollen is organized into definite bodies or pollinia which are more or less pear-shaped and may have a little stalk or caulicle with a viscid disk or gland at the base. These disks stick to insects visiting the flowers and the pollen is thus carried about. Advanced types of pollinia are found in the following genera: *Orchis, Galeorchis, Lysias, Tipularia, Coeloglossum, Corymbis, Ponthieva, Stanhopea,* and many others.

The Dicotyls number at least four times as many species as the Monocotyls and show a correspondingly larger number of extreme and peculiar developments. On a rather advanced level of the Thalamiflorae are the species of the genus *Euphorbia,* which is now usually divided into a considerable number of smaller genera. The flower cluster is a cyathium which in some cases simulates a single flower in appearance very closely, as for example the cyathium of *Tithymalopsis corollata* (L.) Kl. & Garcke. The species of *Chamaesyce* have opposite two-ranked leaves and alternate two-ranked branches, a very unusual culmination type but also present in the related Zygophyllaceae as

in *Tribulus terrestris* L. A most extreme type of cyathium is present in *Pedilanthus tithymaloides* (L.) Poit. Some of the fleshy forms of Euphorbia have bodies that mimic in a remarkable manner the forms and characteristics of the American Cactaceae, including the spines and loss of leaves. Among the extreme types are *Euphorbia obesa* Hook. f. and *E. meloformis* Ait. with bodies more or less spherical in shape.

Near the end of the Thalamiflorae are the blue violets with their showy flowers on very long peduncles that produce little or no seed; but the same individuals develop cleistogamous, apetalous flowers and these are very fertile, producing seed abundantly. In spite of this and numerous somewhat similar cases, some botanists still continue the old delusion that showy flowers are the result of natural selection. In the not distantly related passion-flower (*Passiflora*) there is a special structure developed in connection with the corolla, the so-called corona.

In the Piperaceae, whose systematic position is somewhat doubtful but which represent an advanced condition of flower and inflorescence, we meet with that unique phenomenon in the angiosperms, the 16-celled embryo-sac, present in some species of *Peperomia*. In these female gametophytes multiple fusion of numerous embryo-sac nuclei takes place to produce the primary endosperm nucleus. In one species fourteen nuclei are known to fuse. If a sperm nucleus is also involved, the following endosperm nuclei, numbering about 40, would have a 15-ploid chromosome constitution instead of the usual triploid condition.

The milkweeds belong near the end of the series of Polemoniales. in the Tubiflorae. These plants have evolved a remarkable specialization of the andrecium. The pollen of the milkweeds (*Asclepias* and other genera) is massed together in pollinia which remind one of the massulae in the microsporangia of *Azolla* and the pollinia of orchids. In the milkweeds the two sacs of pollen are joined together by a peculiar connecting piece with a slit in it, in which the foot or proboscis of the insect is caught and thus the pollinia are pulled out of the anthers and carried away. This highly elaborated mechanism is so inefficient that usually in our common milkweed (*Asclepias syriaca* L.), even in the presence of abundant swarms of pollinating insects, less than one in a hundred flowers is ever properly pollinated. The Asclepiadaceae also contain some rather extreme forms with succulent stems and minute leaves, comparable to those of the Euphorbias, cacti, Mesembrianthemaceae, and a few composites.

Near the top of the Scrophulariales are the bladderworts (*Utricularia*) which bear on their leaves, under the water, little bladders which have been designated as the most remarkable structures in the plant kingdom, comparable somewhat to the complex organs of the higher animals. One of the most perfect type is found in *Utricularia macrorhiza* Le Conte. These little bladders are provided with entangling and irritable hairs around the mouth and with a trap-door on the inside. The bladders are contracted in the resting condition and when an unlucky little plant or animal swims up and accidently comes in contact with the irritable hairs, the bladder expands suddenly and the victim is sucked in through the mouth to be definitely imprisoned by the closed trap-door.

In the closely related order, the Lamiales, the highest family is represented by the Lamiaceae and one of its extreme genera is *Salvia*. The species of *Salvia* have evolved a most remarkable andrecium which in the more advanced forms consists of two stamens with only one half of the anther fertile, the other half being developed into a long sterile lever attached to the stamen filament by a movable joint. The whole apparatus represents a very ingenious pollen brush which brushes the back of any insect seeking nectar in the base of the flower. This is without doubt a useful mechanism and works efficiently but other species of the mint family which have no such highly elaborated mechanism for pollination are just as successful as the sage.

Among the Amentiferae, which represent an extreme evolutionary series, apparently distantly related to the lower Calcyflorae, one again finds numerous unusual characteristics. Among these may be mentioned the fruit of the common fig, (*Ficus carica* L.) the woody cup below the acorn of the oaks (*Quercus*), and somewhat similar developments in related genera. The cone-like fruit of alder (*Alnus*) is also remarkable and somewhat similar developments are found in certain Proteaceae. Probably the most unusual manifestation in this highly advanced subclass is the presence of chalazogamy in various genera, as in *Juglans*, *Carya*, *Casuarina*, *Corylus*, *Betula*, etc., in which the pollen-tube, instead of passing along the usual route through the micropyle, penetrates through the base of the ovule. This action indicates that the pollen-tubes have attained the extreme of parasitic ability.

The Myrtiflorae also contain highly evolved groups and one can easily find odd and unique structures among them. In the

cacti are developed many unusual forms of body and spine. Some of the forms are very extreme and simulate the bodies of Euphorbias. Some species of *Opuntia* have very sharp spines with retrorse barbs which, however, are covered with a papery sheath. This sheath develops an abscission zone at the base and is thus easily removed from the spine.

Among the Cucurbitaceae are various extraordinary fruits, such as the squirting cucumber (*Ecballium elaterium* (L.) A. Rich.), watermelon (*Citrullus*), etc. There is an authentic record of a watermelon attaining the enormous weight of 183 lbs. In this region of the plant kingdom also occurs that remarkable monstrosity, the largest flower in the world, produced on a parasitic plant with inconspicuous body and without green leaves, *Rafflesia arnoldi* R. Br. (Rafflesiaceae). This flower weighs about fifteen pounds and measures a yard across. The petals are about a foot in length and vary in thickness from three-fourths of an inch in the thickest part to one-fourth of an inch in the thinnest part. There are several other species of Rafflesia with most remarkable flowers.

Another family of this subclass is the Mesembrianthemaceae which has a number of genera with extremely unique body forms, some of which are supposed by teleologists to simulate pebbles, as in *Mesembrianthemum ficiforme* Haw. Extreme forms of plant body are present in the genera *Lithops*, *Frithia*, *Fenestraria*, etc. The species of Fenestraria have "windows" at their leaf-tips which project out of the ground. The compact forms of these extreme Mesembrianthemums suggest the somewhat similar forms appearing in many species of cacti which seem to be distantly related to them.

The mangrove (*Rhizophora mangle* L.) belonging to the Rhizophoraceae, has several extreme characteristics. The seed sprouts in the fruit on the tree and when the embryo is quite large it drops down into the mud or water. The mangrove also has a remarkable, aerial root system which forms a complex branching prop about the base of the trunk.

Among the Caprifoliaceae are a number of species in various genera that produce twin flowers, as in some species of *Lonicera*, *Linnea*, and *Kolkwitzia*. The latter is also bizarre in producing an elongated neck between the ovulary and calyx which spreads out horizontally somewhat like the pappus bristles of some composites.

In advanced Angiospermae with complex and specialized

complements of hereditary factors, the sequence of differentiation in determinate shoots, as in the inflorescence axis or the flower receptacle, is often changed from the primitive type, where the differentiation gradient follows the order of the cell lineage, to a new sequence. In *Campanula*, as in *C. americana* L. and other species, the spicate flower cluster begins to bloom at the base in the usual way but at the same time the very tip flower also comes into bloom. The remaining flowers of the spike develop in the normal sequence from the lower level to the terminal flower which has passed its blooming period for some time. In the elongated head of the wild teasel, *Dipsacus sylvestris* Huds., the blooming begins in the middle and proceeds toward the base and apex at the same time. A similar sequence is followed in the blooming of the ear and tassel of Indian Corn, *Zea mays* L. In various types of advanced flower clusters, as in *Lacinaria* and in *Nabalus asper* (Mx.) T. & G., the heads begin to develop and bloom at the tip of the stem and continue downward to the base. Many such odd gradients develop in various advanced groups.

The highest family of plants is, without question, the Cichoriaceae. Here the genus *Tragopogon*, to which the common salsify belongs, has evolved a truly wonderful pappus which forms a large parachute on the fruit. This parachute closes up in wet weather and expands when dry. It also has an abscission layer by means of which the plane of the parachute is finally separated from the long stalk that connects it with the achene. In the common dandelion (*Taraxacum officinale* Weber) there is a similar, although less elaborated, parachute, and in addition a much more remarkable development. The plant has evolved diploid parthenogenesis, or virgin birth, for all of its offspring. All the seeds are developed without fertilization and thus the pollen and pollination by means of visiting bees or other insects are of no use whatever to the plant. In addition to these two extraordinary characteristics, the dandelion has the unusual ability to split into new individuals vertically after a certain age is attained and to be rejuvenated during the process, so that after the splitting the juvenile type of leaves is again produced. It is also able to produce a new individual from any little scrap of the root. The dandelion not only has these extreme characteristics but also has one of the most complex if not the most complex complement of general and special hereditary potentialities of any plant in the plant kingdom.

The same principle of the evolution of extraordinary characters in the higher levels is also operative in the various animal series. In the insects, for example, the polymorphic development of members of colonies of ants, wasps, and bees and their instinctive social reactions are extraordinary characteristics. The unusual nest-building abilities of many of the higher birds as compared with the more primitive species or with the reptiles also represent the same evolutionary manifestation.

Man himself is the most remarkable example of the working out of this principle of extraordinary developments at or near the ends of phylogenetic lines, and thus occupies a most unique position among all living things. Man represents the determinate limit of many evolutionary, progressive series. He has attained the limit in his perfectly erect position. He has extreme specialization of fore and hind limbs, suitable for very different activities. The development of the arms, and especially of the hands, of man into remarkably mobile instruments makes them fit alike for feeding the mouth, making tools, playing the most complicated music, writing, and the creation of all art. Man's intelligence would be of little avail without these wonderful organs. Man's face has also reached the limit of position, as compared with the lower animals, in being shifted from a position in line with the dorsal side of the body to a position in line with the ventral side. This shifting, along with the expansion of the brain, has placed the brain instead of the mouth at the end of man's body. Man's voice apparatus and mouth are also extraordinary developments and can be employed in a multitude of ways in addition to their use in speaking and singing. The specially gifted and developed human singer has no compeer among all the vocal animals of the earth.

It is clearly evident to the contemplative scientist, as stated by Henry Fairfield Osborn, that the human brain is the most profoundly marvelous and mysterious object in the whole material universe. It is in some mysterious manner the instrument of the mind, subject to the will of the self-conscious, reasoning, creative, and inventive personality. This small body is more complicated in units of structure or cells and infinitely more complicated in interaction of these units than our entire, heavenly galaxy of suns. It has been estimated, on a conservative basis, that there are over twelve billions (12,000,000,000) of cells in the human brain alone, and it is evident that the

self-conscious personality, my ego, controls this amazing mechanism and other billions of cells of the body to a definite purpose while this sentence is being written. There are about two billions of human individuals on the earth at the present time. Thus, one brain contains at least six times as many structural, biological units as the entire population of the world. One could make a present of six of his brain cells to every man, woman, and child now on the earth. Moreover, each cell has a nucleus with forty-eight chromosomes which can be counted under the microscope and which contain the Mendelian hereditary potentialities or genes. Thus, there are in the brain more than half a trillion chromosomes which, because they form the most important part of the living substance, must certainly be involved in this control of the intelligence and will, not only in producing the inconceivably complex co-ordination involved in the mechanical and chemical activities but also in the production of the conscious thoughts themselves.

Comparing the human brain still further with the amazing numbers which astronomers give of the suns in the starry heavens, the brain does not take any subordinate position in so far as mere numbers are concerned. About one billion stars are within reach of the 100-inch telescope on Mt. Wilson, California. Thus the brain contains more than twelve times as many biological, cell units as the number of stars visible in this great telescope. According to some estimates there are forty billion stars (suns) in our own galactic system. Thus since a man has more than 576 billions of chromosomes in his brain, he carries about in his cranium as many of these important biological units as there are suns in fourteen galactic universes of the size of our own. Carrying this mathematical diversion a little farther, it may be stated that it has been estimated that the normal human body contains twenty-six trillion cells. Thus, with forty-eight chromosomes in each cell, the total number of chromosomes in the human body reaches the marvelous number of more than one quadrillion (1,248,000,000,000,000). In round numbers we can say that our bodies contain as many cells, or structural, biological units as the calculated suns contained in 650 galactic systems the size of our own milky way, and as many chromosomes as the suns of 31,200 galaxies. Thus we can justly exclaim with the Psalmist of long ago: "I am fearfully and wonderfully made."

The mind through the action of the brain recreates the universe from a few simple irritations of nerve endings on the surface of the body, a few pressures on the skin, a few vibrations in the ears, a few rays of light impinging on the retina of the eyes, a few chemical stimuli on the mucus membranes of the mouth and nostrils—these simple irritations impinging on the sensory nerve endings set up nervous impulses which are conveyed along the nerve strands not as touch, sight, sound, taste, or smell but simply as electrical or mechanical processes to be transformed in the hidden chambers of the brain cells into sensations and mental pictures from which each person, through the action of the reason, constructs an intelligent system, a world, a cosmos, a universe. Thus we attain to a knowledge of the outside world as a reality and also to the apprehension of our own selves as distinct from all that surrounds us. This is the determinate limit of the evolutionary process. Then there is another great mechanical marvel, entirely incomprehensible when compared with ordinary mechanisms, namely that sometimes persons have lost considerable portions of both frontal lobes of the brain, with the destruction of myriads of brain cells, without impairment of their intelligence after the wounds were healed, so long as at least one lobe has not been seriously damaged. However, something that poisons or injures a large part of the cellular structure, as for example the presence of narcotics or alcohol, causes a decided confusion in the action of the mechanism. Nor must we forget the fact that all these human brains and personalities are unique. Nature makes an elaborate mould in which to mould one human individual and then throws it away. Each individual becomes a decidedly unique thing in the universe never to be exactly repeated, not even in identical twins. It is evident that a humanity of closely similar individuals would, from a philosophical point of view, be a profound miscarriage of the creative, evolutionary process.

The development of individuality becomes quite pronounced in the higher animals, but is, of course, enormously less than in human beings. Thus our principle of the evolution of unique and extraordinary characteristics at the ends of the progressive, phylogenetic series is seen to be one of the most important and fundamental aspects of the evolutionary process. The result has been an organism with the capability of promoting extreme good or extreme evil in the realm of nature and man. This problem must be a primary concern of scientific study as well as

of moral and spiritual discipline, if the improper use of intelligence and science is not to destroy the very foundations of civilization, through the progressive invention of mechanisms which can be employed for evil and destructive purposes by those who may obtain political and social control. Finally, it must be especially emphasized that the human self-consciousness is a unique phenomenon in the biological realm. A higher animal may think but there is absolutely no evidence that it knows that it is thinking or that it knows of its own existence. If it did it could easily tell us so by word or sign. But not one animal idea has ever been recorded.

The extraordinary developments in man and the higher animals are not to be explained on special teleological grounds. Teleological hypotheses receive no confirmation in fact from a scientific study of the taxonomic systems in relation to their environment. This fact is evident to any one who has the merest acquiantance with the taxonomic system. Mice and men all live in essentially the same environment, and mice usually insist on living in man's immediate domicile; and for mere physical survival men need no more brains than do mice or elephants.

The extraordinary developments, whether mental or physical, are a part of the general evolutionary process and represent peculiar products appearing in advanced members of phylogenetic series, especially in organisms with very complex hereditary systems. They are the results of an intrinsic, mutative process that has been operative in the protoplasm during the geological ages and which we designate, scientifically, by the general term, creative evolution.

Stellar Dynamics

Behind this imposing title is an imposing book written by a man who is master of his subject. The material is for the advanced student and is highly mathematical in its treatment of the several problems which are concerned with the movement of stars in space. The book is a member of the most advanced series of mathematical treatises sponsored by the Cambridge University Press. It is not recommended to any but those who have thorough training in the solution of differential equations and theory of functions. The problems in stellar dynamics are treated in cartesian, cylindrical and polar coordinates. Vector analysis is not used, a fact which is surprising because at least one of the problems discussed could have been treated better by vectorial methods than by those which were used.

The reviewer has worked through that portion of the book which deals with the problem of rotation of the galaxy. The mathematical treatment was found to be straight-forward, definite and clear. Less detailed examination of the remainder of the book indicates that it should be highly recommended to students of dynamical problems in astronomy.—*C. E. Hesthal.*

Stellar Dynamics, by W. M. Smart. viii+434 pp. Cambridge at the University Press; in New York, the Macmillan Co., 1938. $8.50.

A CRITICAL ANALYSIS OF THE MOVEMENTS OF THE SHOULDER-JOINT

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Although much has been written concerning the morphology of the shoulder-joint of the various Tetrapods, as well as the nature of the movements permitted, the writer is of the opinion that certain terms relative to the movements of this joint in man should be clarified. It is generally agreed that, although considerable variation exists in the range of movements, in Mammals the humerus may undergo flexion, extension, abduction, adduction, medial (internal) and lateral (external) rotation round its longitudinal axis and a combination of these movements called circumduction. The term abduction with reference to the shoulder-joint is invariably used to indicate elevation of the humerus laterad and adduction to signify depression of the humerus from the latter position toward the side (mediad).

However, as regards the use of the terms flexion and extension as applied to the shoulder-joint considerable discrepancy exists between the various aspects of anatomy. It is with the interpretation and employment of these terms that the present paper is concerned. The term flexion in general is usually defined, or conceived of at least, as being that movement at a joint whereby the angle between corresponding surfaces of the apposed bones is decreased whereas extension is considered to be that movement in which this angle is increased. The connotation of these terms is evident in the case of angular joints such as the elbow and knee. However, in the case of multiaxial joints, and more especially the shoulder-joint, these movements are rather difficult to classify on the basis of this criterion.

In textbooks of Comparative and Veterinary Gross Anatomy flexion of the quadruped shoulder-joint is interpreted as swinging backward (caudad) of the humerus and extension as swinging forward (craniad) of the humerus. The criterion employed for this classification in these texts is the displacement of the dorsal surface of the humerus with respect to the caudal border

FIGURE 1—A

Skeleton of cat showing the normal position assumed by the various segments of the limbs and the groups of muscles illustrating "mirror image" relation.

A, *Latissimus dorsi*—teres major group of muscles; A^1, Iliopsoas group; B, M. Deltoideus; B^1, M. Gluteus maximus; C, M. Triceps brachii; C^1, M. Rectus femoris; D, Anterior antibrachial mass; D^1 posterior leg muscles and Sh, scapulohumeral angle.

FIGURE 1—B

Human skeleton. The arrows indicate that corresponding segments are "flexed" (?) in opposite directions,

of the scapula (figure 1A) so that flexion (swinging backward) of the humerus results in decreasing the scapulo-humeral angle, whereas extension (swinging forward) results in increasing this angle.

Diametrically opposed to this conception of flexion and extension of the shoulder-joint is the view adopted in the modern editions of most standard textbooks of Human (Gross) Anatomy. For example, in Quain's Anatomy, eleventh edition ('23), under the description of the action of the muscles which operate on the shoulder-joint (p. 115), appears this statement: "The movements of the arm, though difficult to classify, are best described by starting with the humerus in the hanging position. From this position it may be carried directly forwards to the horizontal plane—this movement is usually termed flexion—and then be elevated to the vertical position; oppositely it may be depressed to the hanging position, and then be carried backwards or extended."

Moreover, there is general agreement among human anatomists that the muscles involved in the production of flexion (swinging forward) of the humerus at the shoulder-joint are the coracobrachialis, the short head of the biceps brachii, the pectoralis major and the anterior fibers of the deltoid, whereas those involved in the production of extension (swinging backward) of the humerus are the latissimus dorsi, the teres major, the long head of the triceps brachii and the posterior fibers of the deltoid. In texts of Comparative and Veterinary Gross Anatomy, on the other hand, the flexor and extensor muscles of the quadruped shoulder-joint are classified as just the reverse of those in Human Anatomy.

In older editions of Human Anatomy texts the terms flexion and extension were not employed either in connection with the description of the shoulder-joint or with the muscles which act upon this joint. Apparently the issue was avoided by stating merely that the humerus "swings forward" and "backward" at the shoulder-joint and in the case of the muscles that they "draw the humerus forward" or "backward" as the case may be. However, in the older editions of Gray's Anatomy ('87) under the description of the triceps muscle it was stated that "when the arm is extended (sic) the long head of the triceps may assist the teres major and latissimus dorsi in drawing the humerus backward." It is evident, therefore, that in spite of the fact that these terms were not employed

in connection with the description of the movements of the shoulder-joint the implied meaning of the term "extension" of this joint was similar to that still in use in Comparative and Veterinary gross Anatomy. On the other hand, these terms were evidently employed in the same manner as used today before they were generally adopted in Human Anatomy textbooks as is evident by this statement of Wyman (1867): "If we admit the idea of symmetry in structure between arms and legs, and would compare the movements of the two in men and animals, we must change in some respects the terms flexion and extension, from those ordinarily used in the description of the human body. We will suppose the human skeleton suspended with the vertebral column horizontal, the limbs slightly flexed, the toes and fingers pointing downwards, the palms facing forwards and the soles backwards. Flexion of the humerus would be backwards, of the femur forwards." A review of the literature previous to as well as subsequent to the date of Wyman's paper has failed to cast any light on the question as to the explanation for the adoption of these terms as now used with reference to the human shoulder-joint.

Inasmuch as such a discrepancy exists between the various phases of anatomy with respect to the use and interpretation of the terms flexion and extension of the shoulder-joint, with the resulting confusion experienced by the student and much necessary explanation required on the part of the teacher in Human Anatomy, it occurred to the writer that some effort should be made to analyze the problem with the view to clarifying it or at least to arousing sufficient interest among human anatomists that some agreement eventually be arrived at relative to the terminology employed in connection with the human shoulder-joint. Aside from the academic aspect of the problem it is hoped that its solution would serve to enable the student to make a better adjustment between his courses in Comparative and Human Anatomy.

The objective aimed at in this paper is not to offer an explanation for, or to refute, the present concept of these terms prevailing in Human Anatomy but rather to raise certain questions bearing upon this concept. If, for example, flexion of the shoulder-joint in quadrupeds is regarded as swinging backward (caudad) of the humerus, whereas in biped man it is considered as swinging forward (craniad) can these divergent views be explained on the basis of man's assumption of an erect

posture, that is on the fact that man's pectoral limb was converted from an organ of progression or locomotion into one of prehension? If this explanation is tenable is swinging forward of the humerus of the child who is learning to "crawl on all fours" to be regarded as flexion or extension? Conversely which of these terms should be applied to swinging forward (craniad) of the humerus of those quadruped animals which are able temporarily to assume a biped mode of locomotion, such, for example, as the bear?

The characteristic attitude of the fetus is well known and the advantages of such a posture for conservation of space and for the presentation or passage of the fetus through the birth-canal are obvious. As regards this normal attitude, habitus or posture of the fetus is it true, as De Lee ('33) states and as is generally described, that it is one of flexion of all the joints? In this position the humerus of the child as well as that of most quadrupeds is displaced forward or craniad. Is the shoulder-joint of the human fetus to be regarded as in flexion, whereas, in the quadruped fetus it is to be considered as in extension?

Is it likely that the comparative anatomists are incorrect in their interpretation and that the conception of the human anatomists is the correct one? Or is it possible that the view adopted by the comparative anatomists is correct as regards quadrupeds but that this conception does not hold for biped man? If the comparative view-point is incorrect or, on the other hand, if it holds true only for quadrupeds then of what value is anatomical interpretation of the comparative anatomists to human anatomy in this instance? Or is it perhaps an unfortunate use of terminology employed by both Comparative and Gross Anatomists, that is, a matter of using physiological terms with a disregard to the true morphological relationship?

According to the comparative anatomists the fore and hind limbs of quadrupeds, or the superior and inferior extremities of man, are constructed on a common plan, each limb being divisible into three segments.

Wilder (1866) made the observation that "corresponding segments point and are flexed or extended in absolutely opposite though relatively similar directions." Thus, in the quadruped, as the cat for example, (fig. 1 A), the brachium extends ventrad and caudad, the antibrachium ventrad and slightly craniad and the manus is directed ventrad in alignment with the antibrachium with the palmar aspect facing caudad. In the

hind limb the thigh extends ventrad and craniad, the leg ventrad and caudad and the pes ventrad and craniad. In each limb, therefore, the segments are directed ventrad and craniad or ventrad and caudad so that corresponding segments in the two limbs extend in opposite directions. Moreover, flexion of the distal segments of the limbs involves, in the case of the forelimbs, bringing the palm of the manus toward the caudal or posterior aspect of the antibrachium (fig. 1 A) at the radiocarpal or wrist-joint, and in case of the hindlimb the anterior or cranial aspect of the pes toward the front of the leg at the ankle-joint; flexion of the antibrachium involves approximation of its anterior surface toward the anterior surface of the brachium at the elbow-joint and in the hindlimb flexion of the leg comprises approximation of its posterior surface toward the posterior surface of the thigh at the knee-joint. In the case of the proximal segment of the hind limb it is generally agreed that flexion of the thigh in both man and quadrupeds involves swinging its anterior aspect craniad at the hip-joint. If Wilder's statement be followed to its logical conclusion does it not follow, therefore, that flexion of the brachium would involve swinging its posterior or dorsal aspect caudad at the shoulder-joint, or in other words, decreasing the scapulo-humeral angle?

Does the position of the scapula and humerus of quadrupeds in comparison with those of man form a basis for an explanation of these divergent views? When we analyze the position of the scapula of quadrupeds, as for example the Carnivora, (fig. 1 A), we observe that it lies almost parallel with the median plane of the body, the glenoid fossa facing ventrad, the subscapular fossa mediad, the supraspinous and infraspinous fossae laterad and with its borders or margins directed craniad, caudad and dorsad, respectively. Correlated with the assumption of the upright posture of man was a change in the position of his scapula (fig. 1 B), which is situated on the dorso-lateral aspect of the thoracic wall. This shift backward (dorsad) of the scapula may be explained as resulting from a lateral expansion of the thorax, its transverse diameter having become relatively greater and its antero-posterior diameter relatively less. In man, therefore, the scapula is situated more nearly at right angles to the median plane of the body so that the glenoid fossa faces ventro-laterad, the subscapular fossa ventro-mediad and the supraspinous and infraspinous fossae dorso-laterad.

As regards the borders or margins the (original dorsal) medial or vertebral border lies on a plane almost at right angles to the spinous processes of the vertebrae rather than parallel with them as in quadrupeds; the (original anterior or cranial) superior border is still directed craniad and the (original caudal or posterior) axillary border still faces somewhat caudad but, as a result of the elongation inferiorly of the scapula and of its dorsal position, the latter border is directed ventro-laterad.

In quadrupeds the head of the humerus is situated on its dorsal aspect and, as a result of the position assumed by the humerus of a quadruped while standing or walking, it is directed dorso-caudad in apposition with the glenoid fossa which is directed ventro-craniad. As regards the position of the humerus in man it is well known that in the normal anatomic position of the human body it lies parallel with the longitudinal axis of the body, which in the human is vertical to the supporting surface as compared with quadrupeds in which it is parallel, so that the elbow-joint lies close to the side of the body. The dorsal and ventral (ventro-lateral and ventro-medial) surfaces of the humerus therefore face directly backward (dorsad) and forward (ventrad), respectively. Accompanying the change in the position of the humen scapula and the direction its glenoid fossa faces has been a corresponding change in the position of the head of the humerus which is directed dorso-mediad or almost entirely mediad. This shift in position of its head has been explained by numerous writers as the result of torsion which the bone has undergone. In spite of these evolutionary changes of the human scapula and humerus, including the fact that the transverse axis of the human shoulder-joint for swinging forward and backward has shifted somewhat due to the change in position of the head of the humerus and glenoid fossa of the scapula, does not the scapulo-humeral angle remain approximately the same as in quadrupeds (fig. 1, A and B)?

According to the theory of "mirror relation" as proposed by Parsons (1908) and Geddes (1912) there is a looking-glass symmetry or mirror image repetition of the girdles and segments of the limbs, that is the hind limb of either side is a mirror image of the fore limb of its own side just as it is a mirror image of the hind limb of the opposite side. Thus the caudal border of the scapula corresponds with the cranial border of the ilium, and the lesser trochanter of the femur with the lesser tuberosity of the humerus so that the teres major and subscapularis mus-

cles (fig. 1-A) correspond with the iliopsoas muscle (A^1); the clavicle corresponds with the ischium, the gluteal tuberosity of the femur with the deltoid tuberosity of the humerus and the deltoid muscle (B) with the gluteus maximus (B^1); the infraglenoid tuberosity of the scapula corresponds with the anterior inferior iliac spine, the olecranon process of the ulna with the patella and the triceps muscle (C) with the rectus femoris (C^1); the coracoid process of the scapula corresponds with the pubis and the coracobrachialis muscle corresponds with the adductor magnus, et cetera.

On the basis of this theory, if followed to its logical conclusion, does it not appear reasonable that if the rectus femoris muscle extends the leg at the knee-joint and flexes the thigh at the hip-joint that the corresponding muscle, namely the triceps, which extends the antibrachium at the elbow-joint, would therefore flex, that is draw backward or caudad, the brachium at the shoulder-joint? Similarly if the iliopsoas muscle flexes the hip-joint would not the subscapularis—teres major group, therefore, flex the shoulder-joint?

In conclusion, the question naturally arises as to which of these opposing views conforms to the true morphological or embryological history of the limbs. A brief review of the stages through which the vertebrate limbs pass in their phylogenetic and ontogenetic development brings out the following: when the limbs first make their appearance their longitudinal axes lie parallel with the longitudinal axis of the body and are directed caudad, the ulna and fifth finger looking dorsad and the palmar and plantar surfaces of the manus and pes facing mediad (fig. 2A). In many Mammalia a secondary modification occurs in which the limbs are extended at right angles to the body and lie parallel to each other. In this position each limb presents a dorsal and ventral surface and an anterior or preaxial and a posterior or postaxial border. The dorsal surface of the forelimb, or superior extremity of man, includes the back of the manus and the so-called extensor surface of the antibrachium and brachium while the dorsal surface of the hindlimb, or inferior extremity, includes the dorsum of the pes, the front of the leg and the extensor surface of the thigh. The preaxial border of the forelimb comprises the pollex, radius, lateral (external) condyle and greater tuberosity whereas that of the hindlimb comprises the hallux, tibia, medial (internal) condyle of the femur and the lesser trochanter.

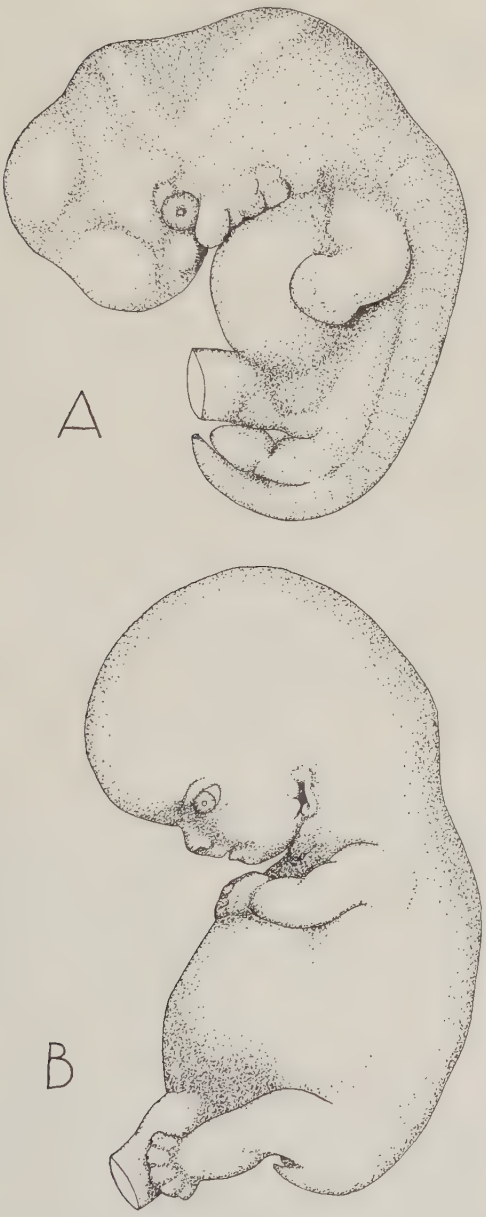

Fig. 2. Human embryos showing position of limbs at A, 31–34 days (11 mm.) and B, 42–45 days (16 mm.), after His.

In a later stage of development the distal extremities of the limbs are directed ventrad, with their longitudinal axes still at right angles to that of the body, the palmar surface of the manus and the plantar surface of the pes face mediad, while the elbow points caudad and the knee craniad (fig. 2B). The next stage is characterized by rotation of the limbs around their longitudinal axes through an angle of 90 degrees, the direction of rotation of the fore and hindlimbs being reversed. Thus the forelimb is rotated laterad with the result that the preaxial border is directed laterad, and the ventral surface faces craniad; the hindlimb is rotated mediad so that its preaxial border is directed mediad, its (original) ventral surface faces caudad and the hallux lies on the inner or medial border of the pes. Finally, in nearly all terrestrial mammals the antibrachium is rotated mediad or pronated so that the manus swings round from the back to the front of the limb with the distal end of the radius overlapping the ulna in which position it remains fixed in most quadrupeds. In the so-called normal anatomic position of man, however, the body is erect and the fore limb or superior extremity is pendant with the palmar aspect of the manus facing ventrad and the preaxial border, that is the pollex, the radius and the lateral border of the humerus, is directed laterad.

CONCLUSIONS

It is generally concluded, therefore, that the hallux is homologous with the pollex, the palmar surface of the manus with the plantar surface of the pes, the tibia with the radius, the knee with the elbow, the ventral or anterior (original dorsal) surface of the leg and thigh with the (original) dorsal or posterior aspect of the antibrachium and brachium and so on. Furthermore, in the light of these conclusions, it is evident that the dorsal musculature of the brachium, that is the triceps complex which extends the antibrachium at the elbow, corresponds with the ventral (original dorsal) musculature of the thigh which extends the leg at the knee; the dorsal antibrachial musculature, which extends the manus and fingers, corresponds with the ventral (original dorsal) musculature of the leg which, however, is said to flex (dorsi-flex) the pes and to extend the toes. As regards the latter discrepancy as well as the action of the dorsal and ventral musculature of the thigh and brachium at the hip- and shoulder-joints, respectively, in the light of

their true morphological relationships what conclusions could be reached?

McMurrich ('23), in discussing this problem, remarked (p. 106) that "It may be pointed out that the prevalent use of the physiological terms flexor and extensor to describe the surfaces of the limbs has a tendency to obscure their true morphological relationships. Thus, if, as is usual, the dorsal surface of the arm be termed its extensor surface, then the same term should be applied to the entire ventral surface of the leg, and all movements of the lower limb ventrally should be spoken of as movements of extension and any movement dorsally as movements of flexion. And yet a ventral movement of the thigh is generally spoken of as a flexion of the hip-joint, while a straightening out of the foot upon the leg—that is to say, a movement of it dorsally—is termed its extension."

If the (original) dorsal musculature of the limbs is to be considered an extensor group and the (original) ventral musculature a flexor group, as is generally held by the majority of morphologists, does it not follow, therefore, in the light of this interpretation, that swinging forward (that is ventrad in the human or craniad in quadrupeds) of the humerus should rightly be termed flexion whereas swinging forward of the femur should in reality be called extension; that bringing the palm toward the ventral aspect of the antibrachium is correctly named flexion, whereas displacement of the sole toward the posterior (original ventral) aspect of the leg, as in "standing on tip-toes" should really be termed flexion rather than extension?

Indeed the whole subject of the action of the musculature of the limbs is badly in need of revision and, insamuch as the present paper is largely analytical and more or less subjective, the writer recommends that the question be thoroughly reconsidered with the view to clarifying the existing confusion.

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AN ANOMALOUS ARTERY IN THE KINGFISHER (CERYLE ALCYON)

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During a recent dissection of two mature specimens of the Belted Kingfisher (Ceryle alcyon), an anomalous artery was observed. The specimens which were used were obtained at the State Fish Hatchery No. 10, near Akron, Ohio, in August, 1937.

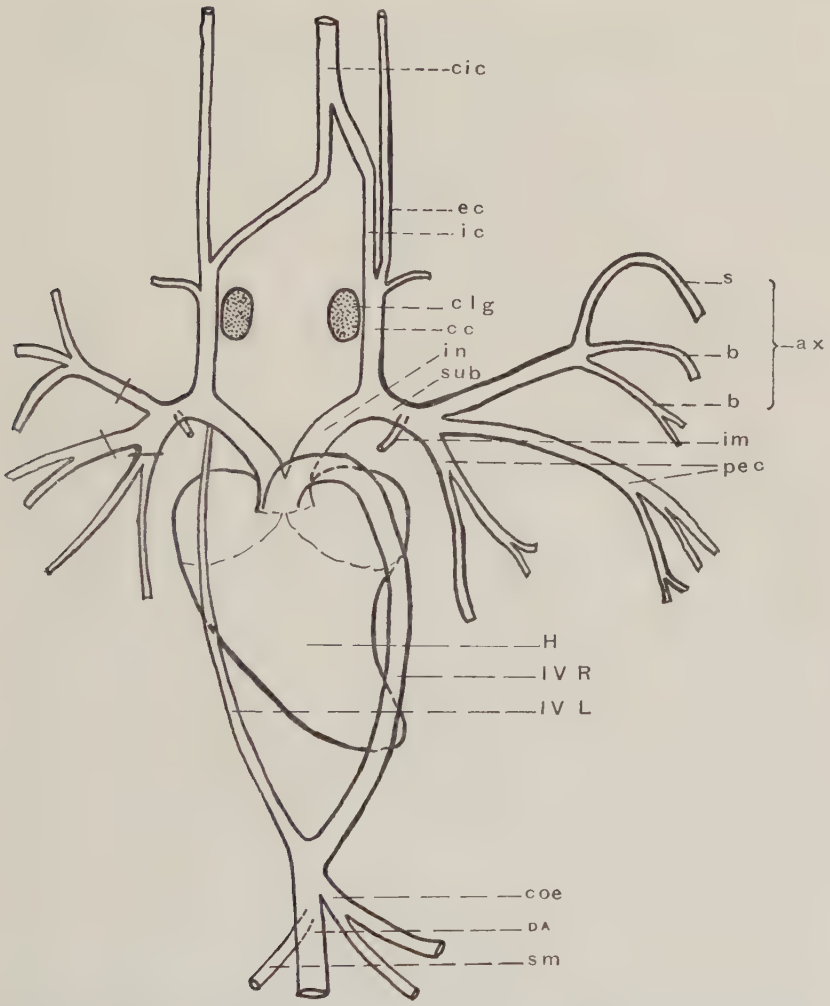
At the posterior end, this vessel arises from the dorsal aorta in the same fashion as the normal 4th right aortic arch (dorsal aorta). It is on the left side of the body just anterior to the coeliac and mesenteric arteries. This left vessel proceeds anteriorly along the sub-vertebral musculature of the thoracic cavity toward the neck where it ends in the muscle fibers and surrounding fascia at the base of the neck just anterior to the left lung. It does not form an anterior ligamentous connection with the right 4th aortic arch or any other major artery at the base of the heart.

Dr. Berry Campbell, of the University of Oklahoma, remarked that there are minute twigs given off all along the course of this vessel. Further he says, "These twigs are not true intercostals, however, and probably in this species . . . the intercostal arteries are branches of a caudal continuation of the vertebral arteries."

There are three primary branches of the aorta giving rise to the right aortic arch and, almost immediatley anterior, to the innominate arteries which then give rise to the subclavian arteries. This differs somewhat from Beddard's expected condition (1) which indicated that the dorsal aorta arises from the right innominate artery.

After consideration of the data given above, the burden of proof seems to indicate that this anomalous artery is a persistent embryonic left 4th aortic arch. It is, therefore, one of the few cases of this kind thus far reported in mature specimens. Beddard (1) refers to injection of a similar vessel in *Spizaetus* and *Aceros*, but no further reference has been located.

Due to the meager amount of literature on this subject, the matter was referred to several anatomists at other institutions. Dr. E. G. Butler, of Princeton University; Dr. D. P. Quiring,



Semi-diagrammatic Sketch of the Main Arteries of the Kingfisher (Ceryle alcyon) in the Region of the Heart—Dorsal View

EXPLANATION OF ABBREVIATIONS

cic—common internal carotid artery
ec—external carotid artery
ic—internal carotid artery
clg—thyroid gland
cc—common carotid artery
in—innominate artery
sub—subclavian artery
s—shoulder branch of axillary artery
b—brachial arteries
ax—axillary artery
im—internal mammary artery
pec—pectoral arteries
H—Heart
IV R—Fourth right aortic arch
IV L—Fourth left aortic arch
coe—coeliac artery
DA—dorsal aorta
sm—superior mesenteric artery

and the late Professor T. Wingate Todd, of Western Reserve University; and Dr. Berry Campbell, of the University of Oklahoma concur in the interpretation that this vessel is a persistent 4th left aortic arch. Dr. W. C. Kraatz and Dr. E. P. Jones, of the University of Akron, made early observations on the two specimens and found that it was located in the position of the embryonic left 4th aortic arch.

REFERENCE

(1) **Beddard, Frank E.** 1898. The Structure and Classification of Birds. London, Longmans, Green and Co.

A Century of Progress

The reader is likely to be a little misled by this book as to the full meaning of the word "Astronomy." Although the volume is entitled "100 Years of Astronomy," little mention has been made of the developments and importance of the work done in that portion of astronomy having to do with fundamental positions of stars and the particular class of problems associated with these positions. The book would have better been entitled "100 Years of Astrophysics." With this idea clearly in mind, the reader can settle back with many hours of enjoyment ahead of him because the book tells a long and fascinating story. Sympathy with the author is quickly established. One has the feeling that he is absorbed in his story; impatient even, to tell it. Although the author makes mistakes from time to time, these will cause the critical reader more amusement than annoyance because all are overshadowed by the author's earnestness in telling his tale forcibly and well. The book is non-technical and can be understood easily by the reader who has only the most elementary knowledge of astronomy. An excellent bibliography of seven pages closes the volume. This reviewer recommends the story to the general reader without reservation.—*C. E. Hesthal.*

One Hundred Years of Astronomy, by Reginald L. Waterfield. 526 pp. New York, the Macmillan Co., 1938. $5.75.

Ion Mobility

This tract is one of a group which provides authoritative accounts of subjects of topical physical interest. With the subject matter treated here the author has been closely connected in research over a period of many years. In fact, most of the material presented consists of results of his laboratory investigations which are sufficiently extensive and complete that they, in themselves, form a connected treatise leading to the best present day knowledge about the motion of ions and ion aggregates in various gases over a large pressure range.

In seven of the eight chapters of about twelve pages each the experimental aspects are interestingly presented—ion sources, methods of measuring ion velocities, detection of ion clusters, diffusion effects and temperature effects. The other chapter is devoted to theory. Thirty-five figures, three tables and a clear handling of the selected essential factual material make this small book a most desirable one for obtaining quickly the salient features of a subject matter that seems, from the research point of view, fairly well completed. The book should prove especially useful to senior college and graduate students in mathematics, physics and chemistry and be a valuable addition to a physical science library.—*M. L. Pool.*

The Mobility of Positive Ions in Gases, by A. M. Tyndall. Cambridge at the University Press, in New York, the Macmillan Co., 1938. $1.75.

THE ORIGIN AND DEVELOPMENT OF THE INTERNAL MUSCULATURE OF THE FROG LUNG (RANA PIPIENS)

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INTRODUCTION

The general literature regarding the histological structure of the frog lung is quite ambiguous on certain points. There is much disagreement concerning the distribution of the arteries and the veins and their relationships to one another. Whether or not cilia are present in the frog lung is also controversial. Neither is there any agreement about the component parts of the alveolar septa; nor is any information concerning their development available. Smooth muscle is known to be present in the lung, but there is no accurate information concerning its distribution and morphology. Therefore, the writer undertook a histological and embryological investigation of these points.

LITERATURE

The veins and the arteries are distributed as companions to one another, according to the sketches of Renaut (1897), and copied by Oppel (1905), Winterstein (1921), and Holmes (1927). This is in complete disagreement with Küttner (1874), Wiedersheim (1882), and Gaupp (1904), who found the pulmonary artery on the periphery of the lung coursing its way from the root to the apex, giving off numerous lateral branches along the way and a main pulmonary vein on the extreme interior, collecting the blood from the intervening capillary network and returning it toward the root of the lung.

Renaut's diagram of a section through the lung is misleading with respect to the distribution of cilia. He shows cilia present only in the tracheal tube at the root of the lung. On the other hand, Küttner, mentioned above, as well as Hoffman (1878), Haslam (1889), and Königstein (1903), find cilia not only in the tracheal tubes, but also on the margins of the numerous longitudinal and transverse septa on the interior of the lungs.

In regard to the internal septal partitions of the lung, Bourne (1909) has stated that they are found less developed in

the lower portion of the lung wall and are completely absent in the apex. This is contrary to the diagrams of Miller (1893), Renaut, and Oppel, who find them as completely formed in the apex and lower portion as in the region near the root.

Of special interest were the accounts of various writers concerning the smooth musculature of the frog lung. Those will be discussed in chronological order.

Arnold (1863) describes the distribution of the elastic and smooth muscle fibers in the alveolar and septal walls of the frog and of the human lung. He speaks of the smooth muscle fibers as being the essential structural constituent of the frog lung.

Küttner (1874) mentions that the smooth muscle forms in the lung of the frog, "a scaffolding for the support of the arteries and nerves, and for the veins a protective cap located in the crown or inner margin of the numerous septa." He ascribes to this musculature the function of a tension regulator, presumably in reference to the intrapulmonic pressure.

Weidersheim and Haslam state that the lung musculature is arranged in large bands which form a network on the interior from which pass finer processes of muscle tissue in the septal walls toward the periphery where they join a thin and incomplete muscular layer in the external wall of the lung.

Thomson (1899) briefly describes the frog lung as a transparent oval sac with muscle fibers in its walls.

Königstein states that a histological section through the amphibian lung convinces one that the greater part of the compact lung substance consists of smooth muscular tissue. He assigns to this musculature the function of diminishing the size of the lung cavity, so that when the glottis is closed, the air in this cavity will be forced out into the peripherally arranged alveoli.

Gaupp (1904) states that the big veins of the lungs course only on the interior in the crowns (Kuppen) of the septa underneath muscle ridges (Randmuskelbalken).

Oppel (1905) has shown by diagram the distribution of smooth musculature in reference to a lung section and to an individual septal partition. In these his emphasis is entirely upon the distribution of the muscle bundles with complete disregard of the veins which are associated with them, in spite of the fact that he includes blood cells in his sketches. Regarding the blood vessels of the lungs, he relies upon the statements of other authors.

Brown (1909) registered graphically small pressure changes in the lung sac, after inhalation, with the glottis closed and attributed them to the contraction and relaxation of the smooth musculature of the lung.

Carlson and Luckhardt (1920) describe the amphibian lung as a paired muscular sac in which the smooth musculature covers the entire wall and extends into the smallest septa of the interior. The arrangement of this musculature is such that its contraction will reduce the size of the lung cavity and raise the intrapulmonic pressure if the glottis is closed. In their studies they report the discovery of a "persistent peripheral motor automatism" which is normally repressed or controlled by inhibitory impulses from the central nervous system. Between breathing movements, (inhalation and exhalation) when the pause is of sufficient duration, they find an initial rise in the intrapulmonic pressure as did Brown, and, like the latter, conclude that it is due to the contraction of the lung musculature rather than to any other possible external or internal factor.

HISTOLOGICAL STUDIES

1. Methods

Histological preparations were made from fifteen frog lungs (Rana pipiens). Each was obtained immediately after pithing the brain and cord. The lungs were then severed at the roots and at once submerged in Bouin's fixative solution. Some of the lungs were prepared in the collapsed, others, in the inflated state. Each specimen was imbedded in rubberized paraffin for sectioning. Some of the series were stained in Delafield's hematoxylin and eosin; others, in orcein, a specific stain for elastic tissue; still others, in Castroviejo's triple stain, which is particularly good for showing muscular tissue distribution and for showing the presence of erythrocytes in the blood vessels. The blood vessels in most of these lungs were injected with India ink from the heart before being severed from the animal. This procedure very effectively aided the study of the distribution of the blood vessels (arteries, capillaries, and veins) throughout the entire lung structure.

2. Discussion and Results

Arteries

According to Renaut, Oppel, and Winterstein, the arteries and the veins are distributed as companions to one another, whereas Küttner, Weidersheim, and Gaupp found a main pulmonary artery coursing its way from the root to the apex, giving off numerous lateral branches along the way. While a principal artery is present in some cases, this distribution is by no means invariable. Serial sections of four lung preparations show that the pulmonary artery divides into two branches.

One of these again subdivides, forming a total of three vessels of uniform size near the root of the lung.

Cilia

Renaut found cilia to be present only in the tracheal tubes. In agreement with Küttner, Hoffman, Haslam, and Königstein, the writer finds cilia not only in the tracheal tubes but also on the margins of the numerous longitudinal and transverse septa throughout the interior of the lungs.

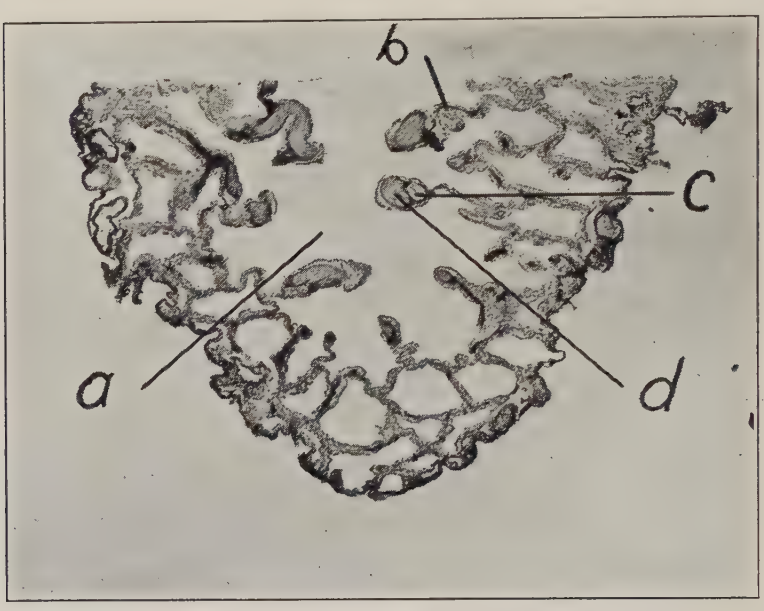

Fig. 1. Longitudinal section near the external wall, showing the peripherally arranged septa: (a) lung cavity, (b) internal septa, (c) small internal vein, (d) internal muscle bundle. 10 ×

Septa

Bourne found the internal septal partitions less developed in the apex of the lung than in the root. This is contrary to the diagrams of Miller, Renaut, and Oppel and to my own observations. They are as completely formed in the apex and lower portion of the lung as in the region near the root. Fig. 1.

Musculature and Venous Return

It is apparent from an examination of the literature that the great amount of disagreement concerns the distribution of the smooth muscle fibers and the venous system of the lungs. A great deal of this is, no doubt, due to the fact that the muscles and veins are structurally so closely associated that many writers investigating the one have failed to observe the other. Because of this close association, it will be necessary to discuss them together.

Most of the authors who have considered the muscular tissue declare it to be a structure independent of the adjacent veins; some of them even failed to observe the closely associated veins. A modification of Castroviejo's triple stain has been particularly helpful in making possible the interpretation of the histological structure of the internal septal marginal veins. Through this stain the muscle tissue appears in green; the white fibrous tissue, in blue; the erythrocytes, in yellow; and the nuclei, in red. With such a stain, that which all the preceding authors have mentioned as an independent muscular network on the interior of the amphibian lung appeared to the writer at first to be a constituent portion of these internal veins. These veins appear to differ from the typical vein in having the smooth muscle tissue, except rarely for a few scattered fibers, assembled asymetrically in a single bundle on their free border. White fibrous connective tissue, which typically is found abundant in both the tunica intima and tunica externa of veins, is, in the case of these septal veins, merged into a single layer for two-thirds of their lumenal circumference. For the remaining third, these layers separate and include the muscle bundle. Moreover, this bundle lies immediately adjacent to the tunica intima of these veins and also possesses numerous interwoven elastic tissue fibers, such as is found in the tunica media of veins. This gives it the appearance of being the tunica media, which has been concentrated in one side.

One cannot escape wondering why there is this peculiar assembling of the muscular tissue of these veins into this single bundle along their internal wall. If the view of the foregoing investigators as to the function of these muscle bundles is accepted, viz., that they act along with the other muscular tissue of the amphibian lung to reduce the size of the lung cavity and thereby raise the intrapulmonic pressure, it is easy to see that from a mechanical standpoint this would be an advantage. A single bundle of muscle fibers located on the free internal border of the septa would act with greater facility and with less impediment in reducing the size of the lung cavity than the same amount of muscle tissue scattered throughout the entire wall of these veins. In a sense this network of muscle bundles is really a complex internal lattice-like sphincter of inter-crossing, longitudinal and transverse, circularly-arranged strands, among which are interspersed elastic connective tissue fibers.

In fact, if the above hypothesis is correct, one may assign two functions to the muscular tissue of these veins, namely: that its contraction will bring about a rise in intrapulmonic pressure and, at the same time, be effective in increasing the blood flow through the pulmonary veins from the lungs. This action would increase the oxygen absorption (Gegenbaur, 1901) of the air in the lung cavity and force the freshly oxygenated blood back to the heart. Both of these functions have their counterpart among mammals in the action of the diaphragm and other inspiratory muscles. Thus, this vascular sphincter would not only perform its normal function of influencing circulation, but also assume a new function of assisting in breathing as well.

Development of the Lung Musculature

The study of the development of the Anuran lung has not extended in the past beyond the very young tadpole. Greil (1905) studied the gross development in *Rana temporaria*, *Bufo vulgaris*, and *Bombinator igneus*. His plates show wax reconstructions of the trachea and lung-bud anlagen, with the veins in blue and the arteries in red. The largest tadpole used was 8.4 millimeters.

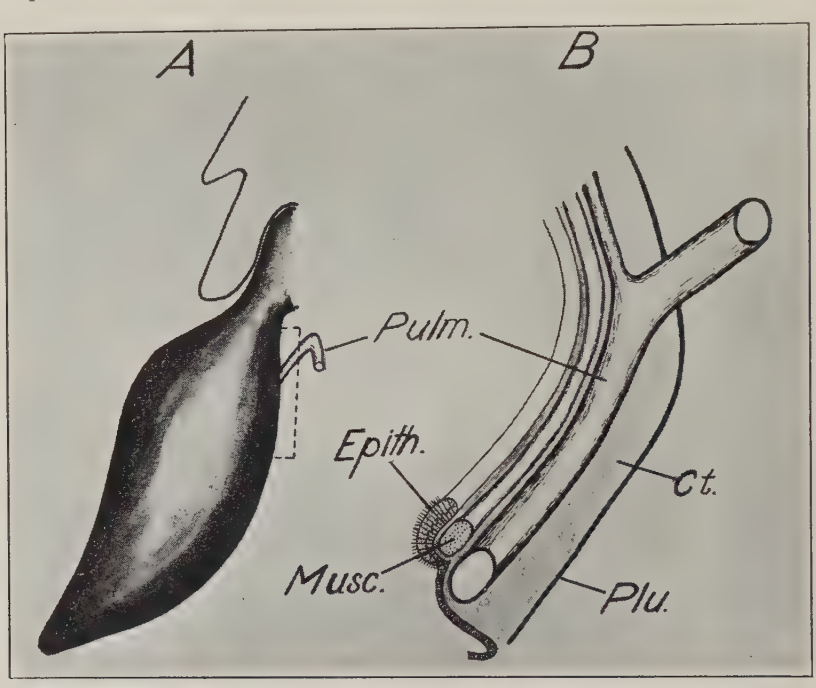

Fig. 2. A. Drawing of the left lung, showing exit of the pulmonary vein. B. Diagram of the dissected lung at portion indicated by dotted line in A. Pulm., pulmonary vein; Epith., epithelium; Musc., muscle; Plu., pleura; Ct., connective tissue.

Fedrow (1910) made a comparative study of the development of the lung veins in various vertebrates. The forms and sizes used were as follows:

Rana temporaria	4.4–11.7 mm.
Triton taeniatus	8.7–11.0 mm.
Lacerta agilis	32–38 somites
Gallus domesticus	3 days
Cavia cobaya	21 days

His object was to show in cross section the similarities of the location and structure of the developing lung sacs and their accompanying blood vessels. In all of his stages, the lung buds were only mere sacs of endoderm with no indication of developing internal septa and smooth muscles.

It seems illogical to think that the muscle network is tunica media because a vein of such construction is, to the writer's best knowledge, not found anywhere else in the animal kingdom. It would seem that the musculature must arise independently of the veins, and the latter become very closely associated with it so as to give a false appearance of being tunica media.

This is borne out by the following facts: The main pulmonary vein originates at the apex of the interior of the lung and courses anteriorly along its meso-lateral border for about three-fourths of the length of the lung. It then passes through the lung wall and proceeds onward to the left auricle. When this vein is on the inside of the lung, it has the same structure as the other veins associated with the musculature. If this muscle bundle is the tunica media of the vein, serial sections of the lung, reading from the posterior to the anterior, should show a transition from the asymmetrical to the symmetrical condition at the point where the vein takes its departure toward the heart. This, however, is not the case. When this point is reached, the muscle bundle continues in association with a tributary vein, while the main vein with a tunica adventitia passes on towards the left auricle. Fig. 2.

Since this problem could not be solved through adult anatomical study, the only alternative left was to study the frog lung from an embryological point of view.

Materials and Methods

The eggs of *Rana pipiens* were collected early in April, and at the time of collection, they were in the neural groove stage. Samples were taken each twenty-four hours for the first week. For the next two weeks, the samples were taken every forty-eight hours and from then on, twice a week until the animals emerged. When the tadpoles reached the stage where hind legs were beginning to develop, the lung buds were carefully dissected out, fixed, and sectioned. The slides were next stained by a dioxan modification of Castroviejo's (1932) method, Waterman (1937).

The critical stages in the development of the frog lung are as follows:

1. Late operculum..... 10.5 mm.
2. ..... 13.5 mm.
3. ..... 16.0 mm.
4. ..... 30.0 mm.
5. ..... 45.0 mm.
6. ..... 60.0 mm.
7. Four legs and long tail..... 58.0 mm.
8. Four legs..... 56.0 mm.
9. Short tail..... 39.0 mm.
10. Very short tail..... 30.0 mm.
11. Tail practically resorbed..... 26.5 mm.
12. Small mature frog
13. Mature frog, medium size
14. Normal mature frog

The sections showing the development of the lung and its musculature were then drawn.

Discussion

The lung develops as an endodermal evagination of the floor of the pharynx. At the late operculum stage, this evagination consists of a single layer of somewhat cuboidal cells. The laryngo-tracheal groove is surrounded by loose mesodermal cells and a few strands of developing

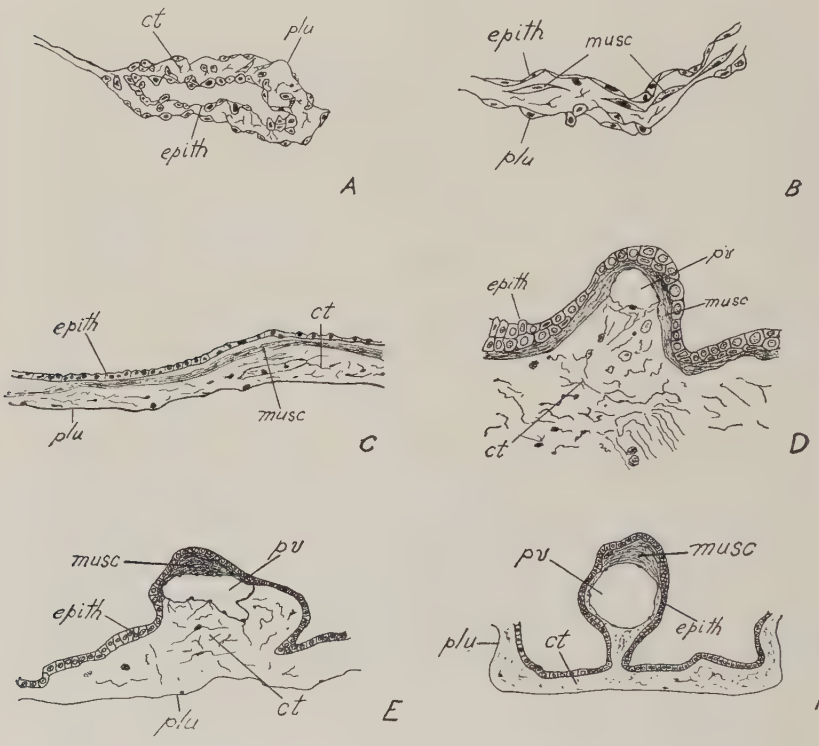

Fig. 3. Camera lucida drawings showing the formation of the alveolar septa and internal musculature of the anuran lung.

A. Lung bud of a 10.5–mm. tadpole of the late operculum stage. epith., epithelium; ct., connective tissue; plu., pleura. 200 ×.

B. Lung bud of a 13.5–mm. tadpole, showing earliest appearances of smooth muscle cells. musc., muscle cells; epith., epithelium; plu., pleura. 400 ×.

C. Cross section of the lung of a 40-mm. tadpole, showing condensed muscle sheet. musc., muscle; plu., pleura; ct., connective tissue; epith., epithelium.

D. Cross section of the lung of a 46–mm. tadpole showing the formation of the rudimentary alveolar septa. pv., pulmonary vein; epith., epithelium; musc., muscle sheet; ct., loose connective tissue. 400 ×.

E. Cross section through the lung of a tadpole with hind legs, showing primitive alveolar septa. Length of tadpole, 56.0–mm. epith., epithelium; musc., muscle fibers; pv., pulmonary vein. 100 ×.

F. Cross section of the lung of a 60–mm. tadpole, taken near the distal end, showing the advanced condition of the musculature. pv., pulmonary vein; musc., muscle bundle; epith., epithelium; ct., loose connective tissue; plu., pleura.

muscle fibers. The anlage of the trachea has the same general structure but more posteriorly becomes somewhat flattened.

The lung buds consist of a single layer of very much flattened and somewhat spindle-shaped cells and are surrounded by very loose connective tissue. No signs of muscle cells are present. Fig. 3A.

By the time the tadpole has reached the length of 13.5 millimeters, muscle cells can be seen developing just under the epithelium. They form a single chain of spindle-shaped cells, which extend around the entire lung. The cells of the epithelium are still flattened, and a few scattered strands of connective tissue can be seen between the pleura and muscle cells. Fig. 3B.

One can best visualize this condition by imagining the lung as being composed of two sacs, exclusive of the plura, one fitting very closely

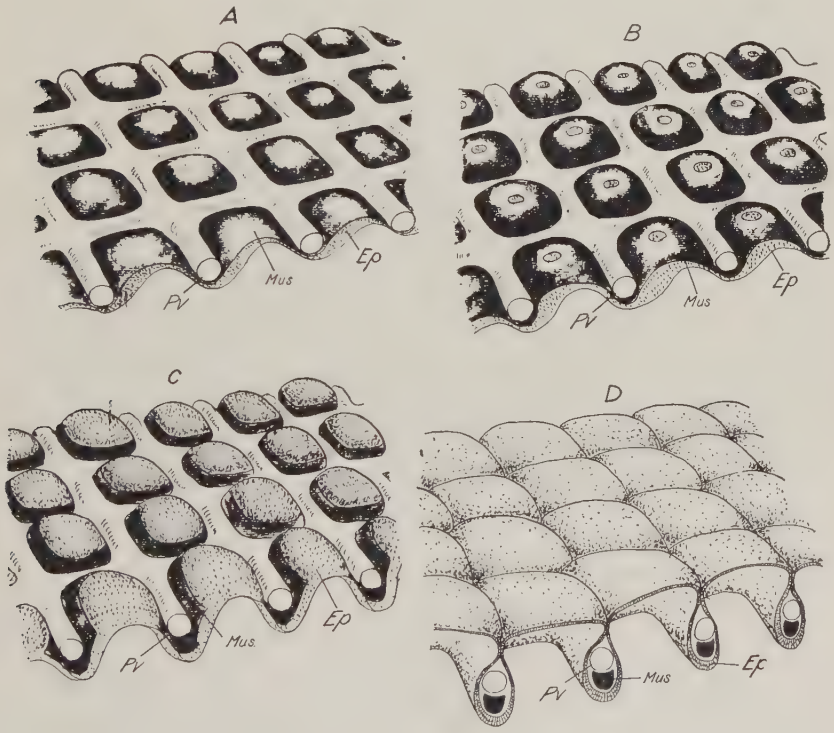

Fig. 4. Diagram showing the formation of the alveolar septa and internal musclature of the Anuran Lung.

A. Lattice-like venous plexus of pulmonary vein with the epithelium and muscular sheets growing through the interstices.

B. Perforations in muscle sheet, exposing the epithelial sheet.

C. Perforations in muscle sheet increase as the muscle thickens over the veins.

D. The muscle is completely condensed over the veins. The epithelium is grown together, forming alveolar septa.

Pv., pulmonary vein; Mus., muscle tissue; Ep., epithelium.

around the other. The inner sac is composed of evaginated endoderm, consisting of very much flattened cells. Around this sac, a second sac fits very closely and is composed of smooth muscle cells, which are loosely joined together.

Very little change can be noticed in the musculature of the lung until the tadpole has reached the length of 40.1 millimeters. At this stage, the muscle fibers have become condensed and extend throughout the interior of the lung just under the epithelium. The cells of the epithelium have become somewhat cuboidal. Fig. 3C.

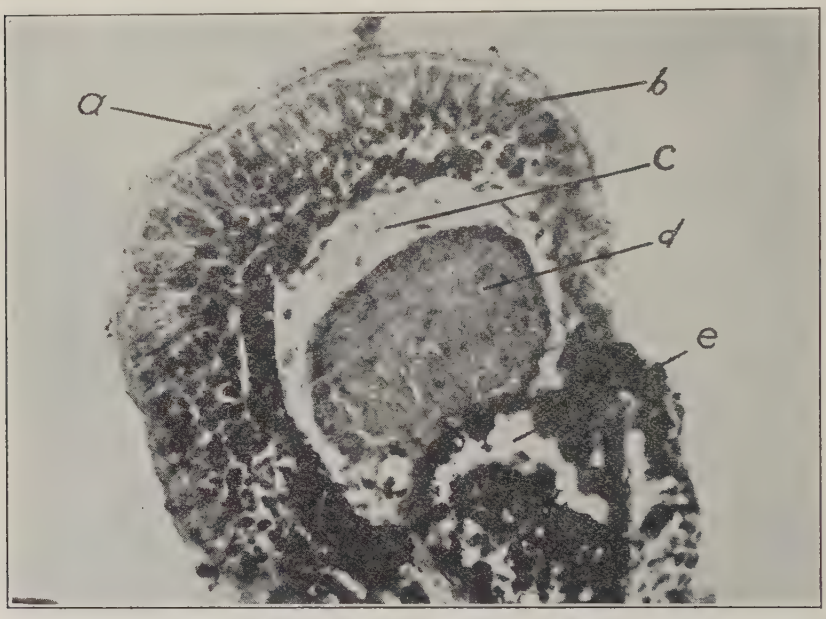

Fig. 5. Highly magnified view of a pulmonary vein and its associated structures: (a) cilia, (b) pseudo-stratified ciliated columnar epithelium, (c) loose white fibrous tissue, (d) muscle bundle, (e) lumen of vein containing India Ink and corpuscles. 800 ×.

The veins can also be seen forming just under the muscle, their walls consisting of a single layer of endothelial cells. The connective tissue underlying the muscle strands is very loose. These veins form a rudimentary lattice-like plexus. The epithelium and muscle strands then grow into the openings of this lattice work. This leaves the veins surmounted by thickening muscle strands and epithelium extending as processes into the lumen of the lung cavity. This marks the first appearance of internal septa. Fig. 3D.

With the appearance of the hind legs, the muscular sac becomes thickened over the internal margins of the venous system. The muscular sac now ceases to be a sac, becomes perforated, and leaves a lattice-like muscular framework that remains permanently associated with the internal border of the venous plexus. Fig. 3E and Fig. 4.

It is interesting to notice that the sections, reading serially from the anterior to the posterior, show that the lungs become more developed toward the apex. This, at first glance, may appear quite contradictory to the well-established fact that an animal develops more rapidly at the anterior end than at the posterior end. However, it is to be remembered that the metabolic gradient, while higher at the anterior end of an organism than the posterior end, is also higher at the ends of the appendages. Thus it would seem logical for the apex of the lung to develop more rapidly than the root, since the lungs arise as appendages of the fore gut, and unless the anterior end remained in a more generalized condition, backward growth would be impossible.

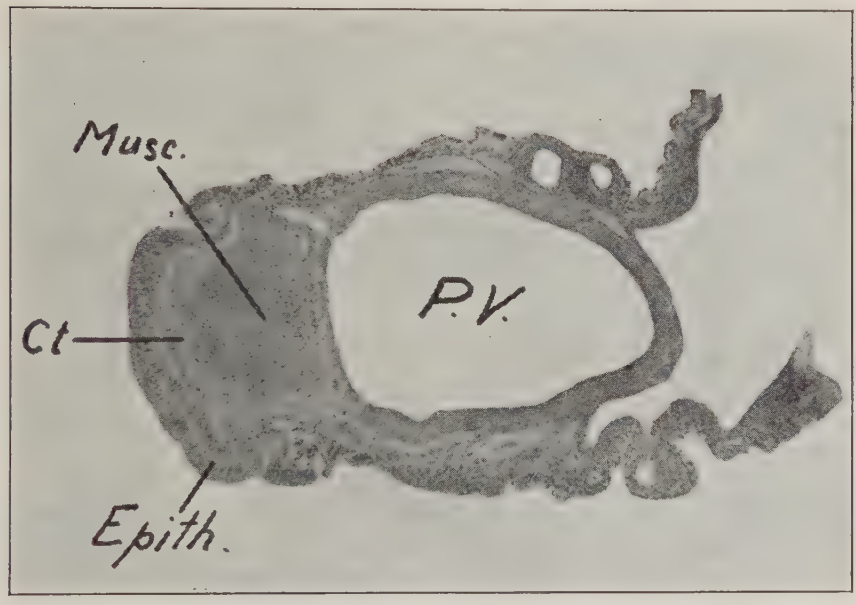

Fig. 6. Cross section through the pulmonary vein of the interior of the frog lung. Musc., muscle bundle; P. V., lumen of pulmonary vein; Ct., connective tissue; Epith., ciliated columnar epithelium.

Towards the apex of the same lung, as shown in Fig. 3E, the musculature, as well as the veins, has become very well developed. The epithelium is now approaching the columnar type, but it is still composed of a single layer of nonciliated cells which are not of the true columnar type as found in the adult organism. Fig. 3F.

Figure 5 shows a high-power photomicrograph of the vein with its connective tissue, muscle bundle, and pseudo-stratified ciliated columnar epithelium. The only comment necessary is that the muscle bundle is not the tunica media of the vein, but it is a structure which has developed in the mesoderm quite independently, and through growth has become very closely associated with it.

The main pulmonary vein, as shown diagrammatically in Fig. 2, when inside of the adult frog lung has the same structure as the other veins. A cross section taken through it shows that the vein and its associated muscles have developed in place and the epithelium has grown around them, leaving a raphae which is visible on the external surface of the lung when examined under high power with reflected light. Fig. 6 shows a photomicrograph through this vein in cross section.

SUMMARY

1. Cilia are found not only in the tracheal sacs at the root of the frog lung, but also on the free internal borders of all the numerous transverse and longitudinal septa.

2. The arteries and veins are not distributed as companions to one another, but independently, the arteries are restricted to the periphery and the veins are located on the extreme interior of the lungs, with the capillaries connecting these relatively widely separated vessels.

3. It is possible for the musculature to affect simultaneously both the intrapulmonic pressure and the venous return of the blood from the lung to the left auricle.

4. Embryonically the frog lung increases in complexity from the root to the apex.

5. The muscle bundle located beneath the epithelium of the alveolar septa is not a part of the tunica media, but is an independent structure, having developed as such, but in close association with the veins.

6. The alveolar septa are formed as follows:

(a) A sac of endodermal epithelium, which has evaginated from the floor of the pharynx, becomes surrounded by a second closely fitting sac, composed of smooth muscle cells.

(b) Around this second sac, a network of blood tubes develops and condenses into a lattice-like plexus of veins.

(c) The epithelial and muscle sheets grow into the openings of this lattice work.

(d) The muscle sheet thins and becomes perforated in the center of the lattice squares and thickens on the lung-cavity side of the veins.

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Marine Mollusca

This little booklet of 87 pages, 5½ x 8½ inches, clearly printed and bound in heavy paper covers, should prove valuable to the student of marine Mollusca anywhere, and not merely on our Pacific coast. Data concerning distribution of the species increase the usefulness of the check list. The bibliography is so selected and organized as to be of greatest possible help to the beginner in this field.

—*W. J. Kostir.*

An Abridged Check List and Bibliography of West North American Marine Mollusca, by A. Myra Keen. 87 pages. Stanford University, California, Stanford University Press, 1937. $1.50.

STUDIES OF THE GENUS EMPOASCA (HOMOPTERA, CICADELLIDAE)

Part VI

Twenty-Two New Species of Empoasca From North America

RALPH H. DAVIDSON
AND
DWIGHT M. DeLONG
Ohio State University

Empoasca necyla n. sp.

Resembling *birdii* in appearance and coloration but with lateral processes as in *radiata* and a dorsal spine as in *spira*. Length 4 mm.

External characters: Vertex produced and bluntly angled. Color yellowish with a median pale longitudinal line, and a basal oblique pale spot on either side. Pronotum with three pale spots on anterior margin. Scutellum with a median longitudinal stripe, and apical third pale. Claval area and sometimes a transverse spot across disc of elytron dark brown in color. Female segment roundedly produced.

Internal male genitalia: Lateral processes long, and slender, apex pointed and curved sharply outwardly, but when crossed before apices these curved tips are directed toward each other. Dorsal spine appearing transverse, directed caudally on basal portion, abruptly bent ventrally and gradually, evenly, narrowed to a curved, medially directed, long slender apex.

Holotype male, allotype female, and male and female paratypes from Warren, Illinois, Aug. 28, 1934 (Frison and DeLong), in collection of the Illinois State Natural History Survey. A male and female paratype in collection of authors.

Empoasca curvexa n. sp.

Resembling *recurvata* in shape of lateral processes but with distinctly characteristic spines. Length 3 mm.

External characters: Vertex bluntly produced and rounded. Color dull green, tinged with golden yellow. Apices of elytra subhyaline.

Internal male genitalia: Lateral processes abruptly curved dorsally at three-fourths their length resembling the lateral processes of *recurvata*. Dorsal spines long, curved ventrally, broad to near apex where they are rather rapidly narrowed to pointed apices. This species can be distinguished from *recurvata* by the spine character.

Holotype male from Edgewater, Florida, April 6, 1938 (DeLong) deposited in the authors' collection.

Empoasca dorothyi n. sp.

Resembling *elongata* in general appearance with lateral processes somewhat like *galluxa* and a characteristic dorsal spine. Length 3.5 mm.

External characters: Vertex rather strongly, bluntly produced, color dull yellow, with a pale spot at apex of vertex, a median pale line and a pale spot next either eye on anterior margin. Pronotum with three pale spots on anterior margin. Apical third of scutellum pale. Elytra golden yellow, subhyaline.

Internal male genitalia; Lateral processes rather short, slightly enlarged on median third, slender at apex, curved caudally and dorsally. Dorsal spines broad at base with a rounded lobe posteriorly, then abruptly curved and narrowed on posterior margin to form a ventrally directed narrow spine at apex.

Holotype male, and paratype male from Oak Creek Canyon, Arizona, Aug. 1, 1938 (Knull) and a male paratype from Flagstaff, Arizona, July 30, 1938 (Knull). Types in the Ohio State University collection and the authors' collection.

The authors take pleasure in naming this species in honor of Dorothy Johnson Knull who has collected and described many interesting Cicadellidae.

Empoasca knulli n. sp.

Resembling *similis* in form and general appearance, with lateral process as in *similis* and a spine as in *bicuspida*. Length 3 mm.

External characters: Vertex broadly rounded, only slightly produced before anterior margins of eyes. Color yellowish green, a median pale line on vertex and an oblique dash at base on each side. Three spots on anterior margin of pronotum, and a broad, pale, longitudinal band on scutellum. Elytra smoky green, veins pale.

Internal male genitalia: Lateral processes broadened on median third then tapered to acutely pointed, slender tips. Dorsal spines broad at base, extending caudally, curved ventrally and narrowed to a bifurcate apex. The anterior spine slightly longer than the posterior and the two are separated by a V-shaped notch. Aedeagus broad, curved slightly caudad and then dorsad.

Holotype male from Huachuca Mts., Arizona, Sept. 9, 1938. (Knull), deposited in the authors' collection.

This species is named in honor of Prof. J. N. Knull who has collected so many interesting undescribed species in the Cicadellidae and many other groups.

Empoasca manda n. sp.

Resembling *plebeia* somewhat in general form and appearance but with distinct genital characters. Length 3 mm.

External characters: Vertex broadly rounded, bluntly produced. Color pale green tinged with yellow.

Internal male genitalia: Lateral processes long, widened on outer margins just before apex to form rounded lobe-like structures, then narrowed abruptly to form finger-like processes on inner margins, the apices of which are slender and waved. Dorsal spines directed ventrally,

rather broad, abruptly and strongly rounded at apex forming structure as in *tamiama*.

Holotype male from Dade County, Florida, collected in March, 1938, (Fisk) and deposited in the authors' collection.

Empoasca pinella n. sp.

Resembling *ponderosa* in form and general appearance, with processes on aedeagus and dorsal spine somewhat as in *coccinea*. Length 3.7 mm.

External characters: Vertex strongly produced, but apex blunt. Vertex, pronotum, and scutellum sordid green tinged with golden yellow. Elytra smoky, often appearing almost black. Face sordid green. Female segment roundedly produced.

Internal male genitalia: Aedeagus with the two proximal long slender processes arising at base as in *coccinea*, but not as heavy nor as deeply notched. Body of aedeagus erect, apical end forming a broad sickle-shaped blade. Dorsal spine broad at base, constricted abruptly to narrow pointed process which is directed downwardly.

Holotype male, allotype female, and male and female paratypes from San Franc. Mts., Arizona, Aug. 12, 1929 (Ball); male and female paratypes from Chiricahua Mts., Arizona (Ball), July 5, 1930, and Tucson, Arizona, Sept. 1, 1929 (Ball). Types in the Ball collection except for male and female paratypes in the collection of the authors.

Empoasca nema n. sp.

Resembling *erigeron* in form and general appearance but with distinctly different lateral processes. Length 3–3.5 mm.

External characters: Vertex broadly bluntly angled. Color, dull green to golden yellow. Vertex usually unmarked, pronotum with three white spots on anterior margin. Scutellum with central portion and apical third pale. Elytra tinged with golden yellow. Female segment roundedly produced.

Internal male genitalia: Lateral processes similar to *erigeron* in shape, narrowed on inner margin to form slender, finger like processes on outer margins. Dorsal spine broad on basal portion, bent abruptly and curved ventrally at caudal margin and narrowed to a long slender apex which is directed anteriorly. Aedeagus erect with a rather long and widened process arising caudally near apex and directed dorsally and caudally.

Holotype male, allotype female, and male and female paratypes from Oak Lawn, Illinois, July 1, 1935 (DeLong and Ross). Male and female paratypes from Alsip, Illinois, Aug. 23, 1934, (DeLong and Ross) and from Des Plaines, Illinois, Sept. 18, 1935, (DeLong and Ross). All types in collection of Illinois State Natural History Survey except for a male and female paratype in the DeLong Collection and the Ohio State University collection.

Empoasca sagitta n. sp.

Resembling *dentata* in form and general appearance but with characteristic dorsal spine. Length 3.7 mm.

External characters: Vertex strongly produced, conical, apex blunt, color dull yellow without definite markings. Elytra subhyaline.

Internal male genitalia: Lateral processes long, slender, touching just before apical portions which are strongly bent outward and pointed at tips. Dorsal spines broad at base tapered to curved slender apical hooks which are curved caudally dorsally and inwardly. Aedeagus slender, a rather long, broad caudal portion arising near middle and extending dorsally and caudally.

Holotype male from White Pine Forest Park, Illinois, July 12, 1934 (DeLong and Ross) and deposited in the collection of the Illinois Natural History Survey.

Empoasca strangula n. sp.

Resembling *obtusa* in form and general appearance but with distinct lateral processes. Length 4 mm.

External characters: Vertex broadly rounded, parallel margined, scarcely produced. Color reddish brown, elytra subhyaline.

Internal male genitalia: Lateral processes appearing slightly concavely notched on ventral side at apex forming a very short blunt process on dorsal margin. Dorsal spines rather large at base with a ventral pointed spur beneath basal portion, the remainder sickle-shaped with the blade strongly curved and tapered to a very slender apex, which is ventrally curved and anteriorly pointed.

Holotype male from Redfish Lake, Idaho, Aug. 3, 1930 (DeLong) and a male paratype from Galena, Illinois, June 28, 1935 (DeLong and Ross). Holotype in the DeLong collection; paratype in the Illinois Natural History Survey Collection.

Empoasca thela n. sp.

Resembling *dilitara* in form, general appearance, and shape of lateral processes. Length 3 mm.

External characters: Vertex broad, bluntly produced. Color sordid green tinted with golden yellow. Elytra dull green subhyaline. Female segment concavely rounded either side of a central lobe.

Internal male genitalia: Lateral processes enlarged on apical two-thirds to apex which is abruptly narrowed on ventral margin forming a curved, slender finger-like process. Dorsal spines, short and broad, directed ventrally, almost straight on anterior margin, strongly convex on posterior margin to form a bluntly pointed apex. Aedeagus erect, a long sickle-shaped process very broad at base, arising on caudal margin at apex, and a long slender process on each side just below base of the larger process. These structures are curved caudally and then dorsally from point of attachment.

Holotype male (Nov. 22, 1910), allotype female (Dec. 6, 1910) and female paratype (Dec. 6, 1910) from Brownsville, Texas. One female paratype from Katherine, Texas, Dec. 3, 1911, and a series of male and female paratypes from Brownsville, Texas, Aug. 8, 1937 (Knull), all deposited in the collections of the authors and the Ohio State University.

Empoasca ocala n. sp.

In general appearance resembling pale specimens of *fabae* but male genital characters more like *ancistra*. In the latter species the lateral processes of male are slender before the inwardly curved portion and the dorsal spine is not gradually tapered to slender apex. Length 2.5 mm.

External characters: Vertex produced and bluntly angled, color yellowish or pale green. Two greenish spots on disc of vertex. Female last ventral segment roundedly produced.

Internal male genitalia: Lateral processes long, in lateral view appearing rather broad, definitely widened just before apical third which is strongly curved inwardly and abruptly narrowed, the two processes contiguous and curved outwardly to form rather long slender apices which are divergent and directed laterally. Dorsal spine sickle-shaped, rather broad at base, curved, gradually narrowed to slender apical third which is directed anteriorly.

Holotype male, allotype female, and a large series of male and female paratypes from Ocala Forest, Silver Springs, Florida, collected March 20, 1938 (DeLong). Types in the collections of the authors and the Ohio State University.

Empoasca mesolinea n. sp.

Resembling *osborni* in general form. Smoky, marked with a median pale line across vertex, pronotum, and scutellum. Length 3.5 mm.

External characters: Vertex broadly rounded, parallel margined. Face with a dark brown band on either side between which is a pale median line that continues across vertex, pronotum and scutellum. A pale spot on pronotum behind each eye. Elytra dark greenish, a smoky line along commissural line with claval suture brownish. Apices of elytra smoky. Female segment roundedly produced.

Internal male genitalia: Lateral processes long, enlarged near apex and in ventral view with a finger process on inner margin of enlargement. In lateral view clavate, appearing to have a terminal curved finger process arising from apex of the rounded, enlarged apical portion. Dorsal spines rather heavy at base directed caudad then ventrad, tapering from base to form long slender spines. Aedeagus directed dorsad, terminal third erect, ovate, with a short anterior spine at base.

Holotype male and allotype female from Huachuca Mts., Arizona, July 20, 1937 (Knull) in authors' collection.

Empoasca amara n. sp.

Resembling *radiata* in coloration but paler and with vertex more bluntly angled. Length 3.5 mm.

External characters: Vertex bluntly angled only slighter longer at middle than next the eyes. General coloration, green marked with orange. Vertex and pronotum dull green mottled with orange; basal angles of scutellum orange. Elytra pale, with three light orange longitudinal stripes, one each on clavus, costal area and corium, while in some specimens these areas are entirely orange. Apices smoky, veins pale. Female last ventral segment roundedly produced.

Internal male genitalia: Lateral process long, slender, apices very narrow, curved outwardly, divergent. Dorsal spine short, basal half broad, transverse apical half directed ventrad, tapered rapidly to a slender pointed apex. Aedeagus enlarged on apical third with a pair of short spines at base of enlargement. These spines are directed posteriorly and the tips are slightly curved upwardly.

Holotype male, allotype female, and a large series of male and female paratypes from Davis Mts., Texas, June 2, 1937, and Sept. 20, 1938, (Knull) in the authors' collection and the Ohio State University collection.

Empoasca kaibaba n. sp.

Resembling *medora* in general appearance but with lateral processes as in *recta* and dorsal spine somewhat like *pelecana*. Length 3–3.5 mm.

External characters: Vertex broad, blunt, slightly produced. Color yellowish tinged with orange. Elytra dull golden iridescent, the veins pale, causing them to appear striped. Female last ventral segment roundedly produced.

Internal male genitalia: Lateral processes simple, a little longer than styles, apices pointed. Dorsal spines short, broad, anterior margin slightly concave; posterior margin more strongly rounded to form pointed ventral apex. Aedeagus erect, apical portion branched, an arm extending from both sides to dorsal spines, and a rather long slender caudal portion produced caudad and dorsad.

Holotype male, allotype female and female paratype from Kaibab, Utah, June 21, 1937. Also male and female paratypes from Flagstaff, Arizona, June 23, 1937, and June 28, 1937, all collected by D. J. and J. N. Knull. Types in the authors' collection and the Ohio State University Collection.

Empoasca uvalda n. sp.

A small species, resembling *bifurcata* and *bicuspida* in general appearance, but with characteristic lateral processes somewhat like those of *spira*. Length 3 mm.

External characters: Vertex produced and bluntly angled; colored dull green, with a median, pale, longitudinal stripe and a pale spot on disc of either side. Three pale spots on margin of pronotum. Elytra rather uniformly golden green, apices slightly smoky. Female last ventral segment roundedly produced.

Internal male genitalia: Lateral processes slender bent abruptly ventrally near apices which are pointed. Dorsal spines broad at base, apical half sickle-shaped, directed ventrad and rapidly narrowed to slender pointed apex. Aedeagus erect, apex with bifurcate arms and a caudal projection near apex.

Holotype male, allotype female and male paratype, from Brownsville, Texas, Aug. 8, 1937, (Knull) and male and female paratypes from Uvalde, Texas, Aug. 4, 1937, (Knull). Types in the authors' collection and the Ohio State University Collection.

Empoasca ancistra n. sp.

Resembling *recurvata* in general appearance but with vertex more produced and lateral processes somewhat as in *radiata*. Length 2.5 mm.

External characters: Vertex distinctly produced but bluntly angled. Color apple green marked with darker green to brownish. Elytra dusky, venation paler, marked with longitudinal streaks of brownish pigment of variable intensity between the veins. Apices of elytra dusky. Last ventral segment of female roundedly produced.

Internal male genitalia: Lateral processes tapered to slender apical portions which are strongly bent outwardly near apices. Dorsal spines short, basal half widened and directed caudad, apical half directed ventrad and tapered to a very slender tip.

Holotype male and allotype female from Oak Creek Canyon, Arizona, Aug. 15, 1938 (Knull). Male paratypes from Huachuca Mts., Arizona, July 20, 1937 (Knull). Types in the authors' collection and the Ohio State University Collection.

Empoasca hecta n. sp.

Resembling *cerea* in form and general appearance but with distinct lateral processes and a dorsal spine which resembles that of *decora*. Length 2.75 mm.

External characters: Vertex bluntly produced, of sordid green color with a faint median line and a pale spot next each eye at base. Pronotum with a row of pale spots along anterior margin. Elytra with apices smoky, veins pale.

Internal male genitalia: Lateral processes short, tapered to slender, straight apices. Dorsal spines rather broad at base extending caudad, apical third more slender, curved ventrad, blunt at apex and rounded. Aedeagus erect, three caudal processes arising about middle. The central process is longer and is directed more dorsad than the lateral shorter pair.

Holotype male from Davis Mts., Texas, Sept. 20, 1938 (Knull) and a male paratype from the same locality collected Aug. 2, 1937. Types in authors' collection and the Ohio State University Collection.

Empoasca madra n. sp.

Resembling *diverta* in general coloration, but larger in size and with more produced head. Lateral processes resembling those of *amara*. Length 3 mm.

External characters: Vertex strongly produced and bluntly angled. Color of vertex brownish green with a median pale longitudinal line, a pale spot around each ocellus and a larger one at the base next either eye. Pronotum with a pale spot behind each eye and a pale spot at middle. Apical half of scutellum pale. Elytra smoky tinged with green; basal portion, spots on clavus, and apical third brown. Veins of apical portion paler in color.

Internal male genitalia: Lateral processes long, slender, apical fourth slender and strongly curved laterad, then gently curved dorsad. Dorsal spine broad on basal half which is directed caudad at the apex of which it curved to slender apical, ventrally directed half.

Holotype male from Huachuca Mts., Arizona, collected July 20, 1937, (Knull). Type in authors' collection.

Empoasca galluxa n. sp.

Resembling *ancistra* in general form and appearance, but with distinct lateral processes and a dorsal spine somewhat like that of *ratio*. Length 3 mm.

External characters: Vertex strongly produced and bluntly pointed. Color pale yellowish, mottled with paler yellow, a darker stripe extending from base to apex of elytron just anterior to claval suture. Last ventral segment of female roundedly produced.

Internal male genitalia: Lateral processes short, slender, only a little longer than styles, gently curved dorsad. The tips of these processes are gently, concavely notched on inner margin. Dorsal spines broad at base deeply roundedly notched on anterior margin forming a ventrally directed rounded lobe from the anterior apical portion of which arises a narrow finger-like spine directed anteriorly and curved ventrad.

Holotype male and allotype female from Santa Rita Mts., Arizona, July 13, 1937, (Knull) and male and female paratypes from Huachuca Mts., Arizona, July 20, 1937, (Knull). Types in authors' collection and the Ohio State University Collection.

Empoasca utrica n. sp.

Resembling *birdii* in general appearance and coloration but with dorsal spines roundedly inflated at base and with distinct lateral processes. Length 4 mm.

External characters: Vertex bluntly angled, produced before margins of the eyes. General coloration, pale yellow. Vertex with a pale marking at apex connected with a median pale line and with two oblique dashes at base. Pronotum with three pale spots on anterior margin. Scutellum with a broad median pale band. Elytra with claval area sometimes brownish.

Internal male genitalia: Lateral processes long, rather broad at base, concavely narrowed on outer margin to slender processes which are enlarged at three fourths their length by slightly convexly rounded outer margins, then tapered to pointed apices. Dorsal spine roundedly inflated dorsally at base, curved to apical half which is slender and directed ventrally and slightly anteriorly.

Holotype male from Poudre R. Canyon, Colorado, Aug. 22, 1931, (Beamer), and a male paratype from Republic, Washington, Aug. 6, 1931, (Beamer). Holotype in the collection of Dr. R. H. Beamer and paratype in authors' collection.

Empoasca tamiama n. sp.

Resembling *bifurcata* in coloration and general appearance but with blunter vertex and a short, bluntly rounded, lobe-like spine. Length 3.5 mm.

External characters: Vertex strongly produced and bluntly angled. Color green tinged with golden yellow, a pair of round green spots on disc of vertex. Female segment broadly angularly produced.

Internal male genitalia: Lateral processes resembling those of *ziona*, being long, straight, with apices slightly concave on upper margins. Aedeagus in lateral view broad, erect, apex truncate, with a rounded

notch on anterior margin near apex. A long heavy spine arises on posterior margin near base which is erect and curved caudad at the middle and extends to the apex of the pygofer. Dorsal spines short, rather broad, directed ventrad and rounded at apex somewhat as in *solana*.

Holotype male, allotype female, and a large series of male and female paratypes from Tamiami Trail, Florida, March 31, 1938, (DeLong). Types in the authors' collection and the Ohio State University Collection.

Empoasca gampsoa n. sp.

Resembling *elongata* in general form but with characteristic shape of lateral processes and dorsal spine. Length 4 mm.

External characters: Vertex distinctly produced and bluntly rounded, with a T-shaped mark, the top of which is at the apex and a pale spot on each side near the base next to each eye. Yellowish to greenish in color, apical third of scutellum paler. Elytra subhyaline tinged with golden yellow. Female segment roundedly produced.

Internal male genitalia: Lateral processes rather long narrowed on apical fourth which is bent laterad. These are usually crossed one third this distance from apex so that the apices are proximal and convergent. The tips of these processes are flattened and enlarged, appearing pad-like. Dorsal spines broadened from base, the caudal ventral angle strongly rounded. The anterior ventral angle strongly curved mesad and ventrad and slightly twisted to form a rather short apical spine. Aedeagus erect with the caudal process bifurcate at apex.

Holotype male, allotype female, and male paratype from Graham Mts., Arizona, Aug. 28, 1933 (F. H. Parker). One male paratype from Pinal Mts., Arizona (Parker), three female paratypes from Huachuca Mts., Arizona, July 20, 1937, (Knull), and three male paratypes from Oak Creek Canyon, Arizona, Aug. 1, 1938, (Knull). Types in the authors' collection and the Ohio State University Collection.

A Bibliography of Statistical Methods

The author of this book (or more strictly speaking, the editor) has had much success in the past in compiling bibliographies on various educational, psychological and personality tests. He has now turned his attention to research and statistical methodology. The result is a rather complete compilation of books, from 1933 to 1938, on this subject, covering actuarial mathematics, agriculture, biology, business, economics, education, engineering, forestry, history, marketing, medicine, psychology, sociology and vital statistics. For each book there is given a series of critical reviews culled from various scientific journals both here and abroad. The books are listed alphabetically by author; in addition there are various indexes, including a classified index, an index of titles and an index of authors and reviewers. The evaluations cover books published in many countries, thus making this compilation an extremely valuable source of reference to anyone engaged in the design and execution of experiments.—*L. H. S.*

Research and Statistical Methodology Books and Reviews of 1933-1938, edited by Oscar Krisen Buros. vi+100 pp. New Brunswick, N. J., Rutgers University Press, 1938. $1.25.